Supporting Information

Synthesis, Luminescent Properties, and Growth Mechanisms of $YF_3:Yb^{3+}/Er^{3+}$ Nanoplates

G. Murali,[a] Byeong Hoon Lee,[a] R. K. Mishra,[a] Jae Myeong Lee,[a] Sang-Hwan Nam[b], Yung Doug Suh[b,c], Dong-kwon Lim,[d*] Joong Hee Lee [a] and Seung Hee Lee [a*]

[a.] *Applied Materials Institute for BIN Convergence, Department of BIN Fusion Technology and Department of Polymer-Nano Science and Technology, Chonbuk National University, Jeonju, Jeonbuk 561-756, Korea.*

[b.] *Laboratory for Advanced Molecular Probing (LAMP), Korea Research Institute of Chemical Technology, Daejeon 305-600, South Korea*

[c.] *School of Chemical Engineering, Sungkyunkwan University, Suwon 440-746, South Korea.*

[d.] *KU-KIST Graduate School of Converging Science and Technology, Korea University, 145 Anam-ro, Seongbuk-gu, Seoul, 136-701, Korea.*

* Corresponding authors: Prof. Seung Hee Lee, lsh1@chonbuk.ac.kr, Tel: 82-63-270-2343, Prof. Dong-kwon Lim, dklim@korea.ac.kr

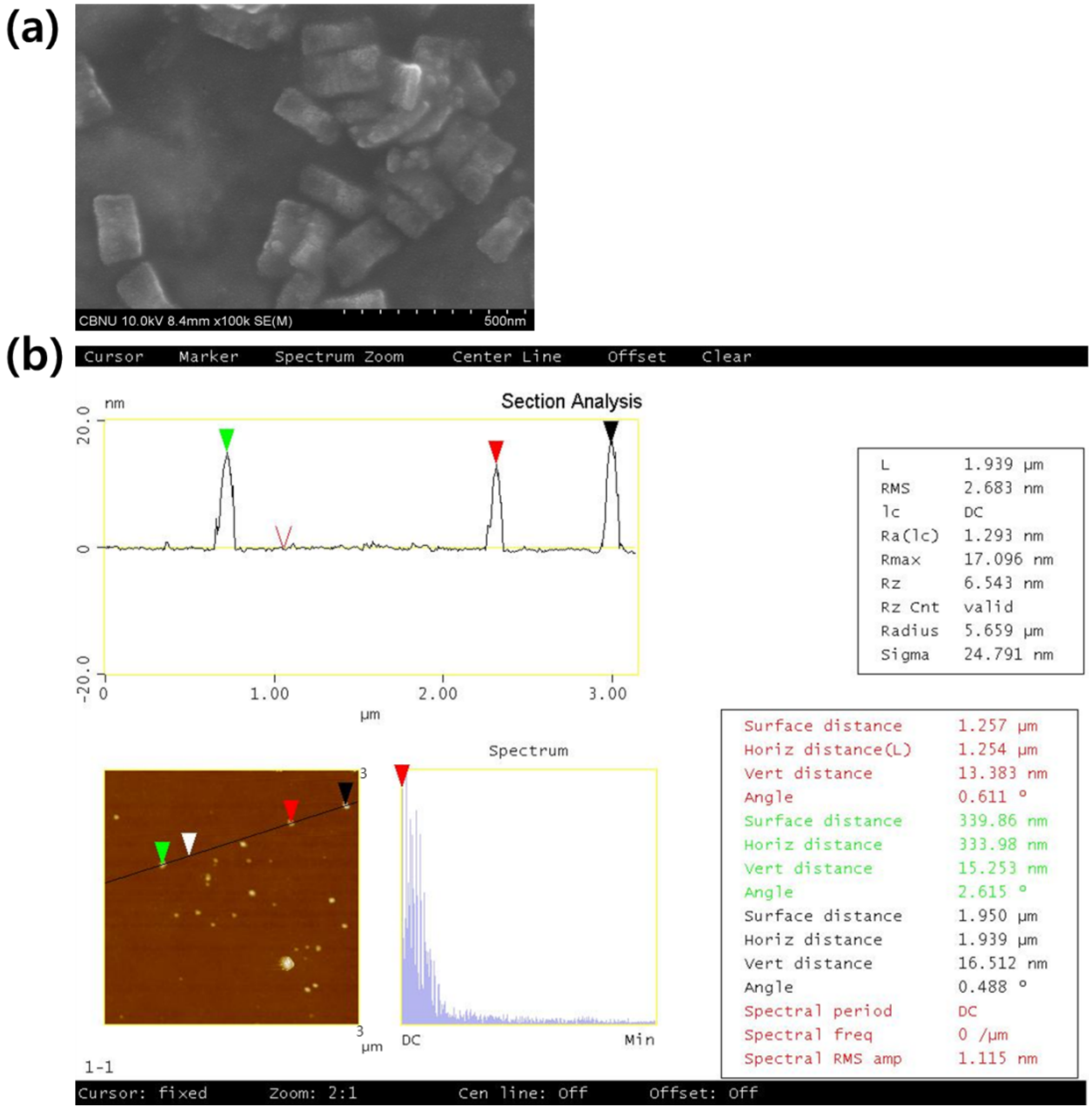

Fig. S1 (a) FESEM image of as-prepared $YF_3:Yb^{3+}/Er^{3+}$ nanoplates. (b) AFM image and corresponding height profiles of nanoplates.

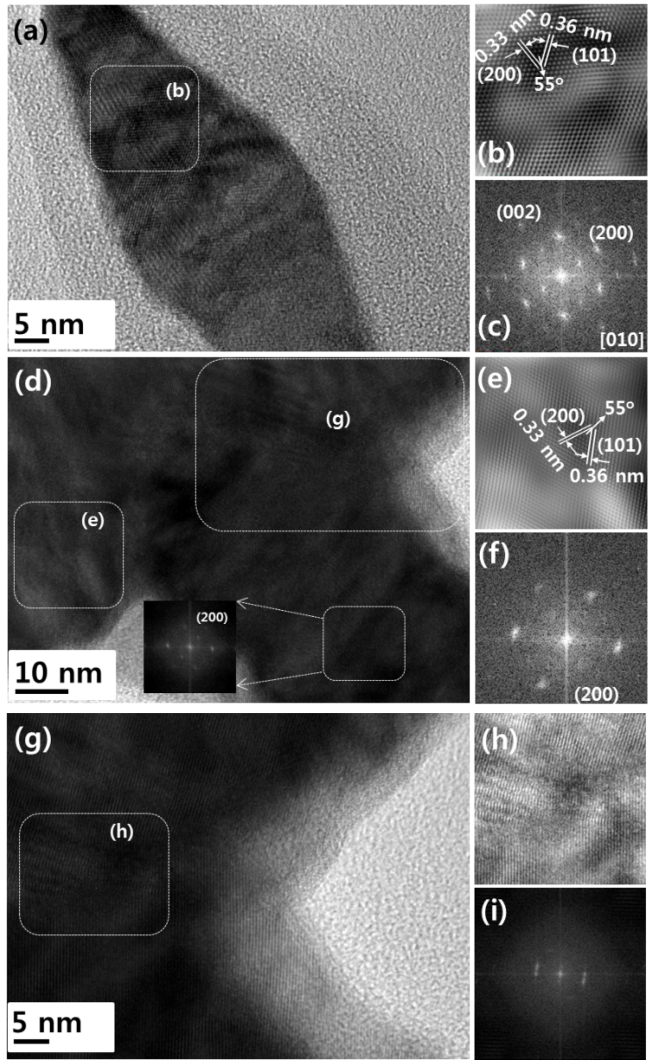

Fig. S2 (a) TEM, (b) HRTEM, and (c) SAED images of *a* YF_3:Yb^{3+}/Er^{3+} nanopod. (d) TEM image of tripod, (e, f) HRTEM and SAED images of *the* parent nanopod. (g) TEM, (h) HRTEM, and (i) SAED images of branching point *in* a tripod. The inset in (d) shows the SAED pattern of *the arm* branching from the parent nanopod.

Fig. S2(a)-(c) show the typical TEM, HRTEM and SAED images of YF_3:Yb^{3+}/Er^{3+} monopod. HRTEM image with crystal lattice shows interplanar distances of 0.33 nm and 0.36 nm corresponding to the (200) and (101) lattice planes of YF_3, respectively (Fig. S2(b)). The clear spots with symmetric SAED pattern shown in Fig. S2(c) indicate the single crystalline state of nanopod. Combining the SAED pattern and the HRTEM image, the crystal growth of the nanopod tip is preferentially along [002] direction and the flat exposed surface of a nanopod is [010]. The tripod, shown in Fig. S2(d), has a geometry in which the parent nanopod is elongated in a [002] direction while one arm branches out from the middle of the nanopod in [002]. According to HRTEM analyses at the joining point, this type of new morphology originates from an interpenetration twinning (Fig. S2(g)-(i)). The two pods i.e., parent and newly originated nanopods are displaying the same characteristic lattice images (Fig. S2(d)-(i)). The HRTEM measurements of tetrapod show that, two single crystalline arm branches growing in [002] are evolved from the parent nanopod (Fig. S3). Accordingly, it is reasonable to believe that the new arm branch of a tripod continues its growth on the other side to form the second sharp tip and caused the formation of tetrapod. Further, it is also observed that the side surface of nanopods in tetrapod is rough to some extent and small extensions which are orderly stacked to nanopod side surface were identified (Fig. S4). This indicates the presence of lateral growth in nanopods through selective absorption of newly formed nuclei. It seems quite reasonable that, if the lateral growth in nanopods of a tetrapod is enhanced, the interspace between the nanopods will be filled, resulting in eventually the formation of two dimensional nanoplate.

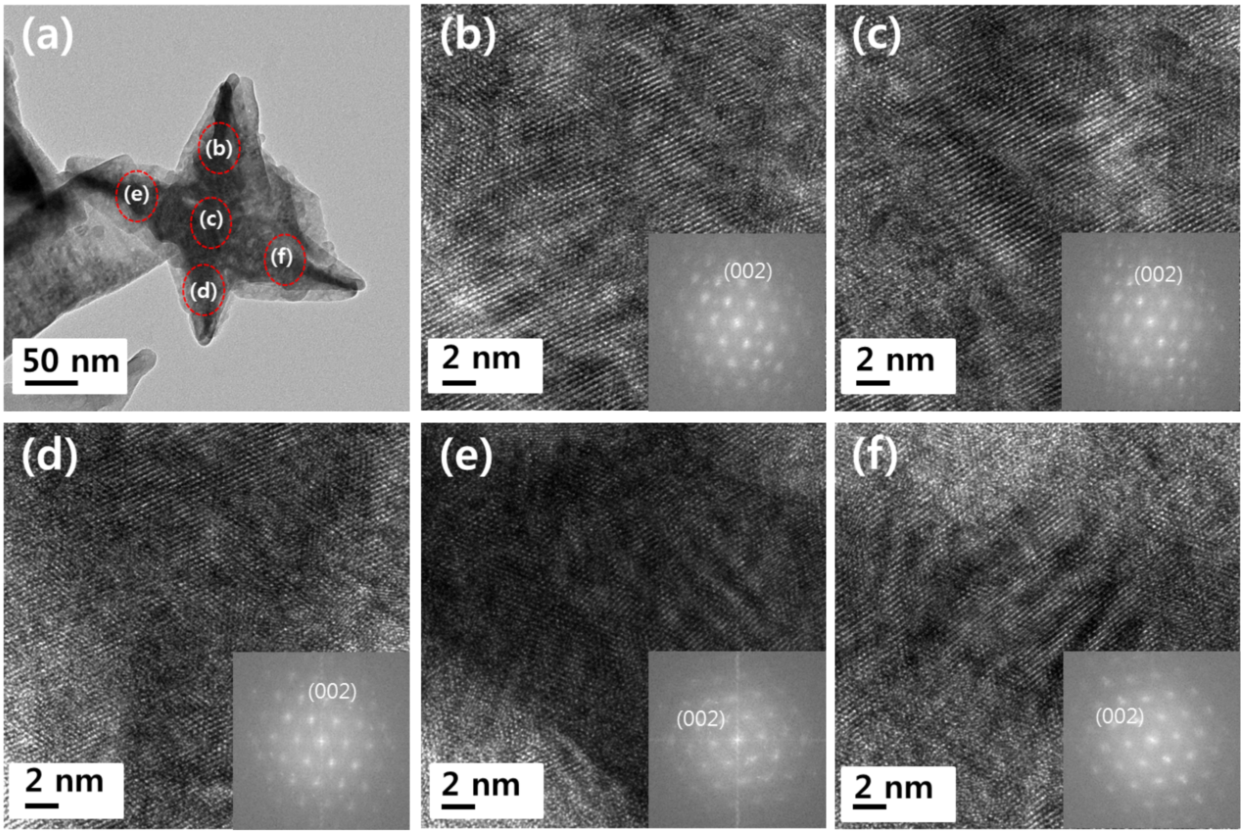

Fig. S3 (a) TEM image and (b-f) HRTEM images of respective locations as identified in panel (a). Insets in panels (b), (c), (d), (e), and (f) are SAED patterns of the HRTEM images.

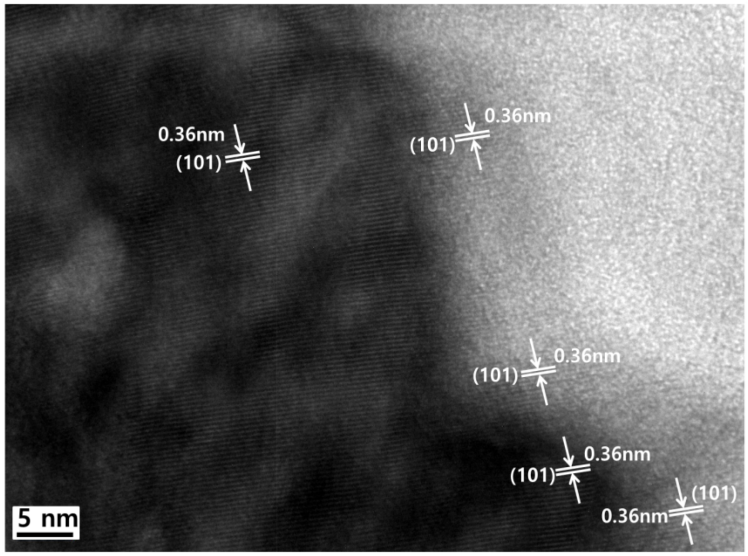

Fig. S4 HRTEM image of one of the nanopods' side surfaces in a tetrapod.

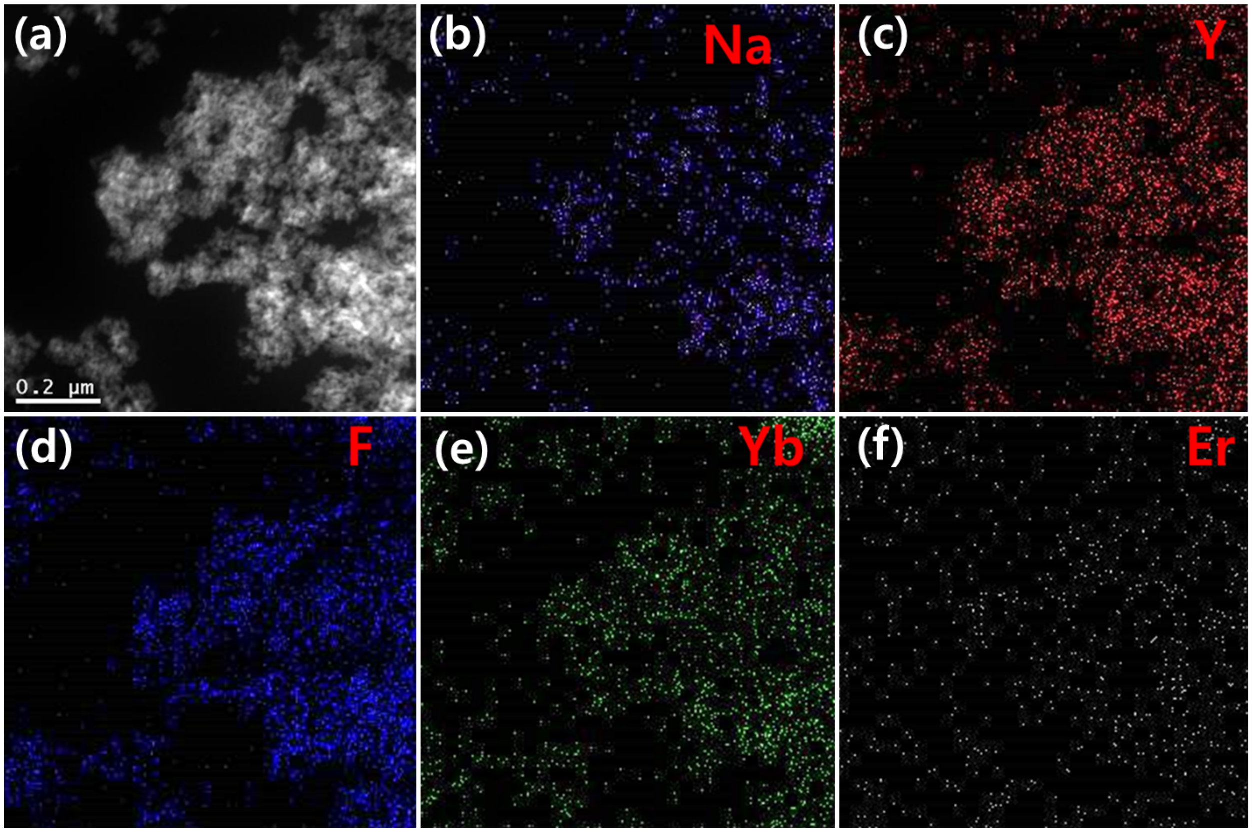

Fig. S5 (a) FETEM and (b-f) elemental mapping images for Na, Y, F, Yb, and Er of $NaYF_4$:Yb^{3+}/Er^{3+} nanoparticles.

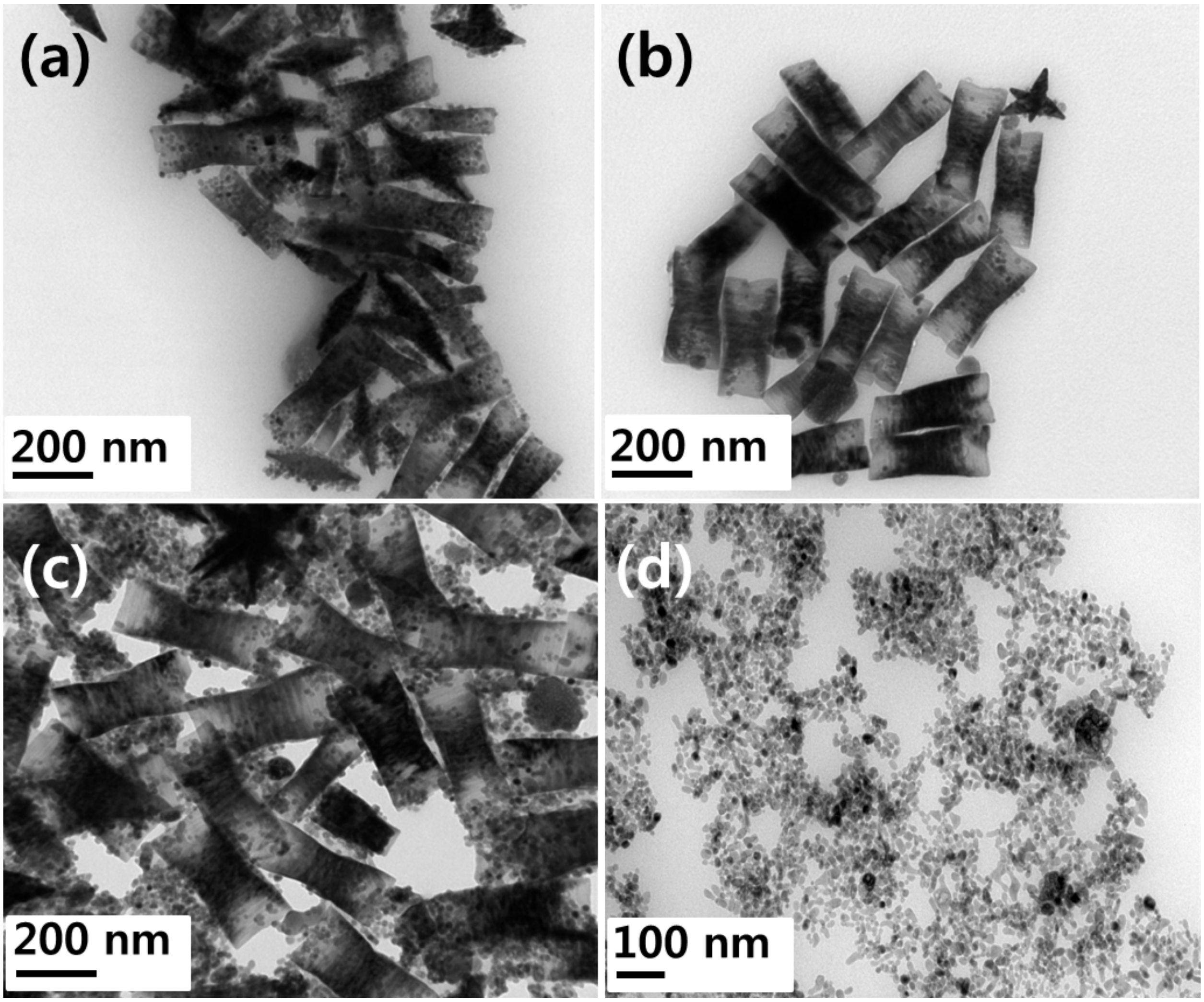

Fig. S6 TEM images of samples prepared with different NaOH concentrations*:* (a) 0.75 mmol, (b) 1.25 mmol, (c) 1.75 mmol*,* and (d) 2.25 mmol.

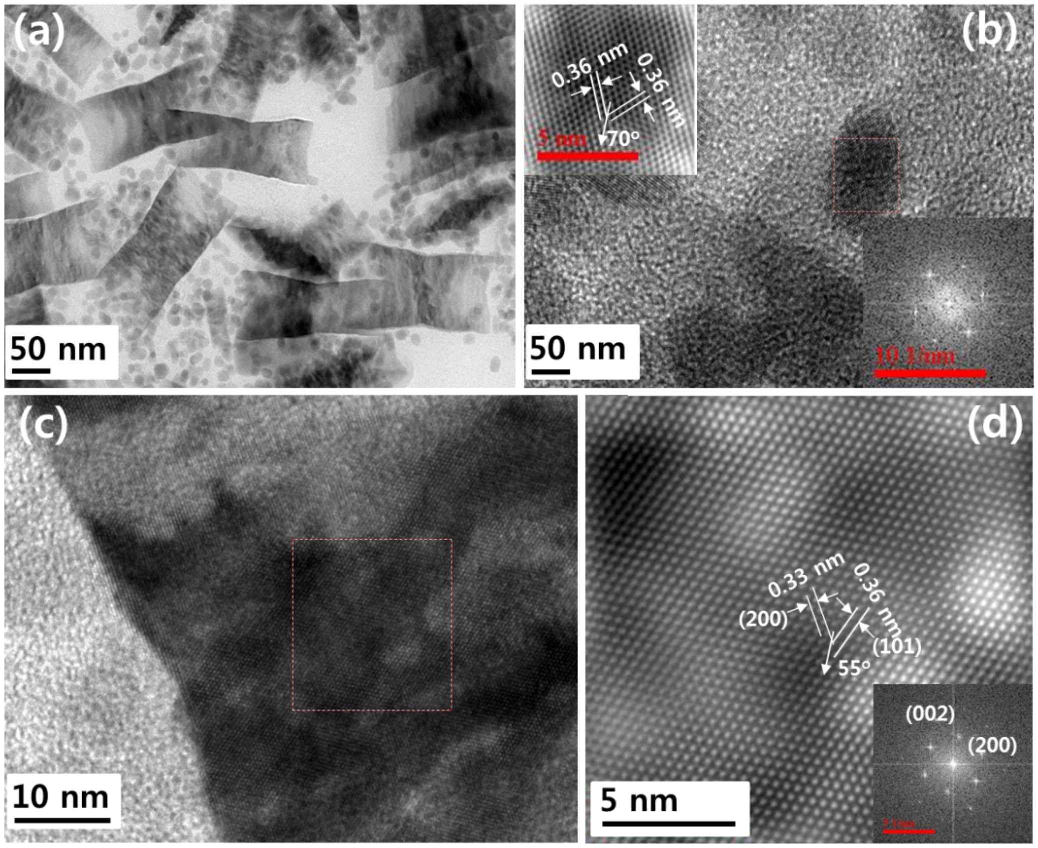

Fig. S7 (a) TEM image of sample after 1 h of reaction. (b) TEM image of particles present in the sample; left inset shows HRTEM image of particle and right inset displays the corresponding SAED pattern. (c) TEM and (d) HRTEM images of nanoplate. Inset in panel (d) shows the corresponding SAED pattern of the nanoplate.

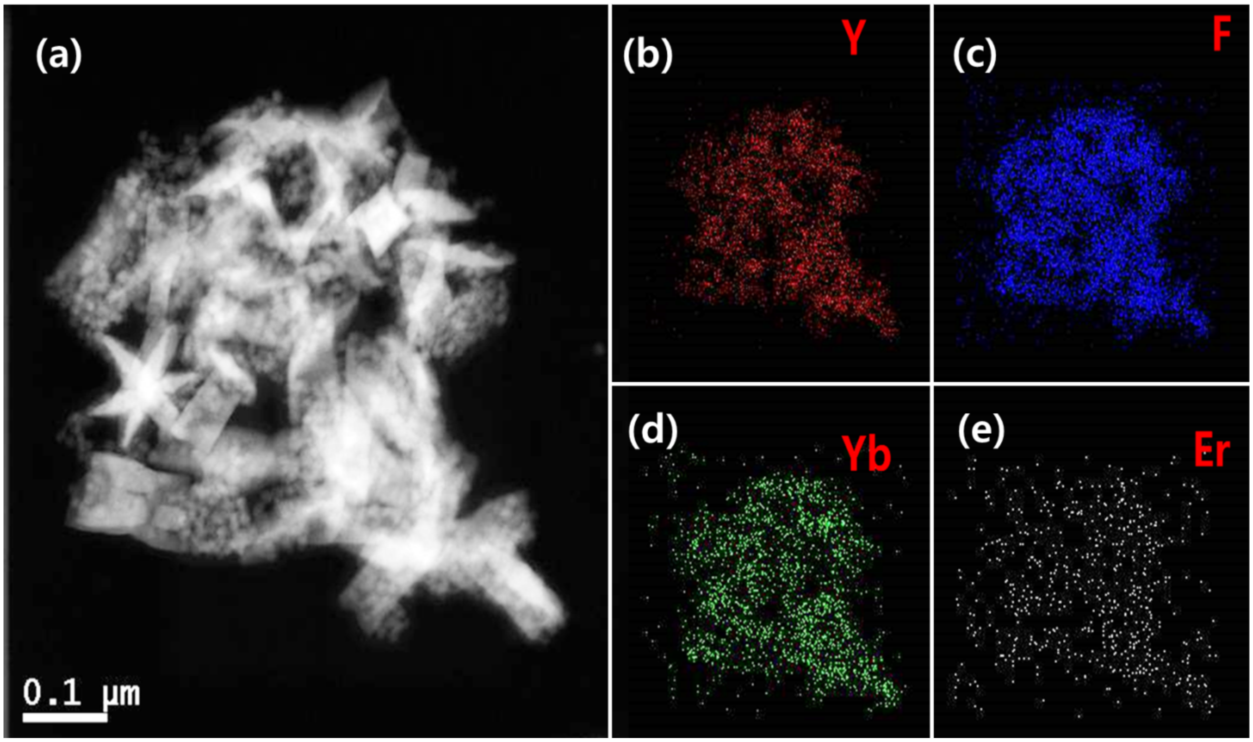

Fig. S8 (a) FETEM and (b-e) elemental mapping profiles for Y, F, Yb, and Er of sample after 1 h of reaction.

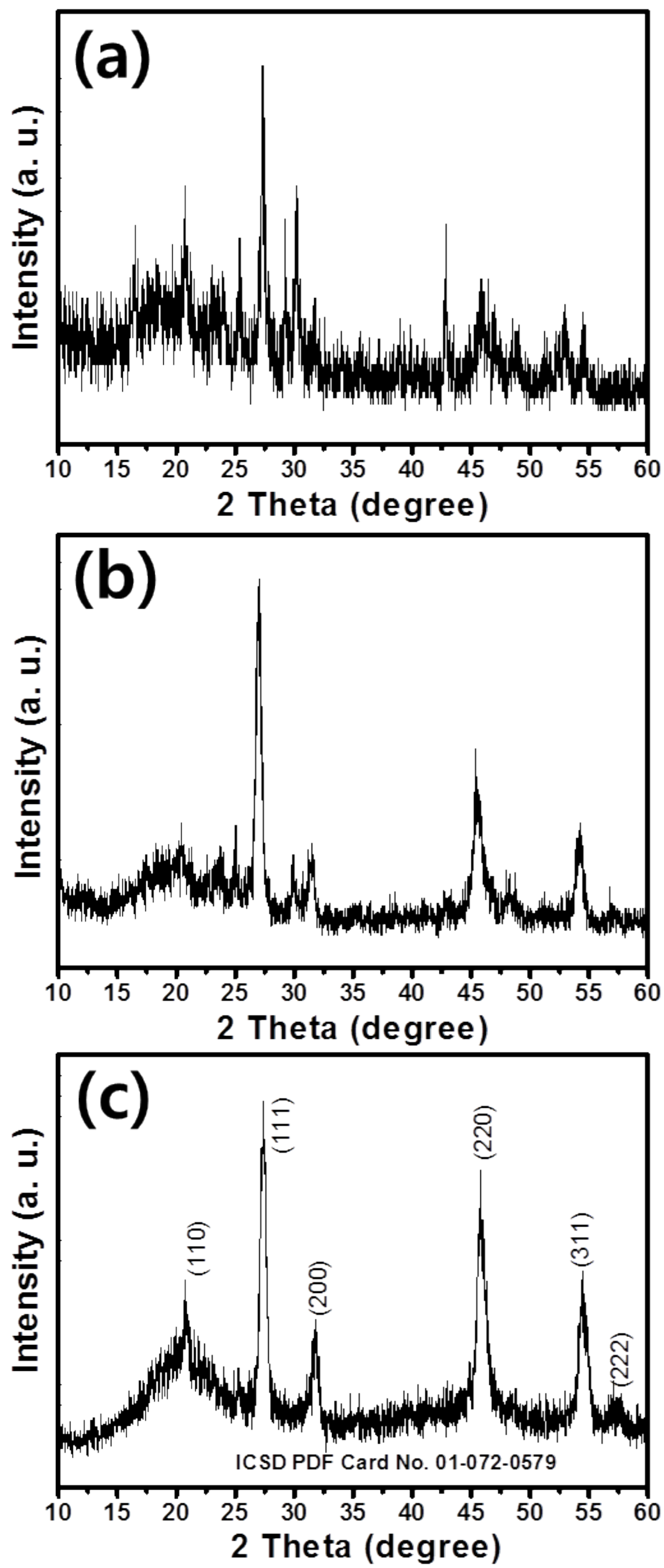

Fig. S9 XRD patterns of samples prepared with different surfactant compositions: (a) 100% OA, (b) 1:1 OM/OA mixture, and (c) 1:1 OM/TOP mixture.

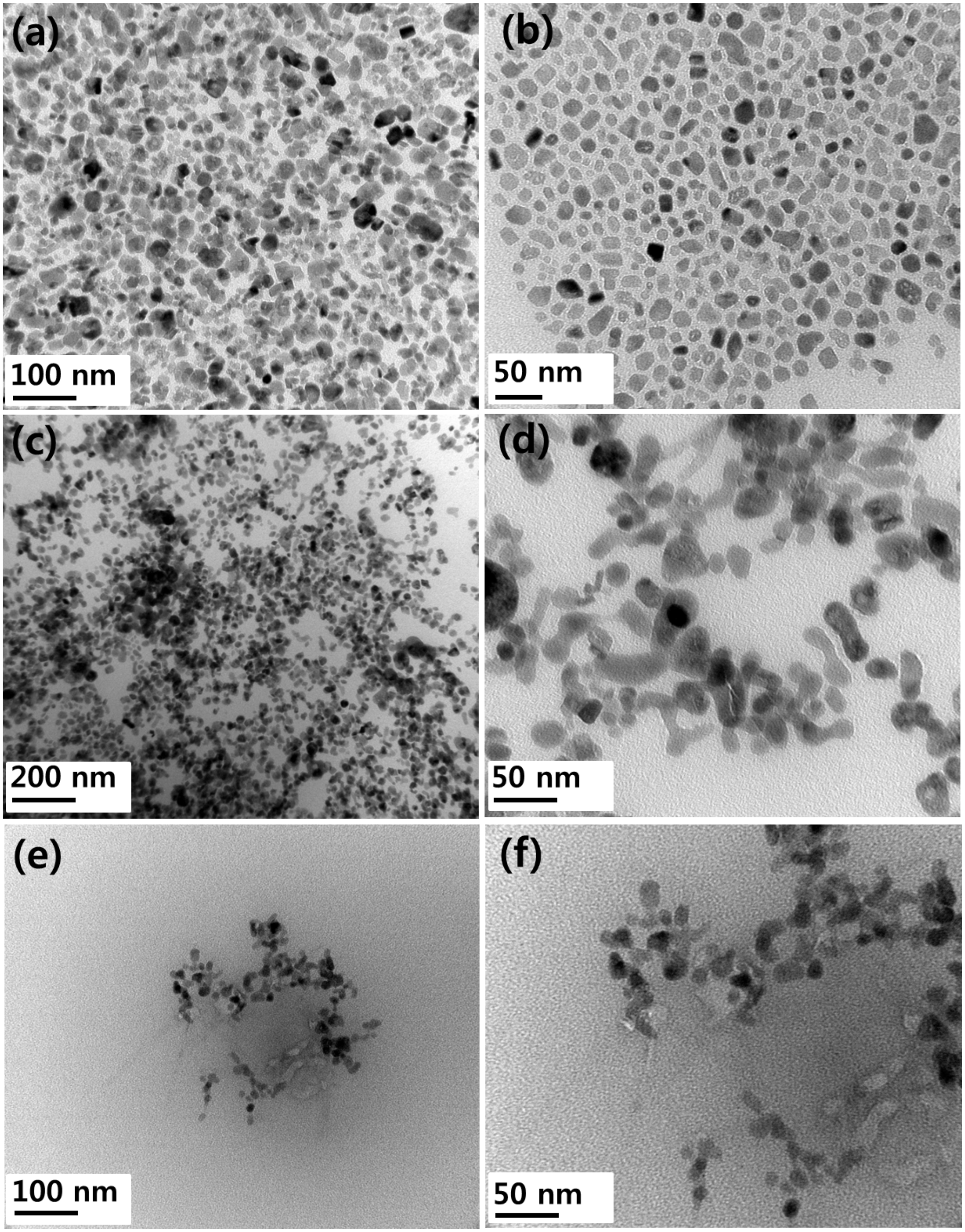

Fig. S10 TEM images of samples prepared with different surfactant compositions: (a, b) 100% OA, (c, d) 1:1 OM/OA mixture, and (e, f) 1:1 OM/TOP mixture.

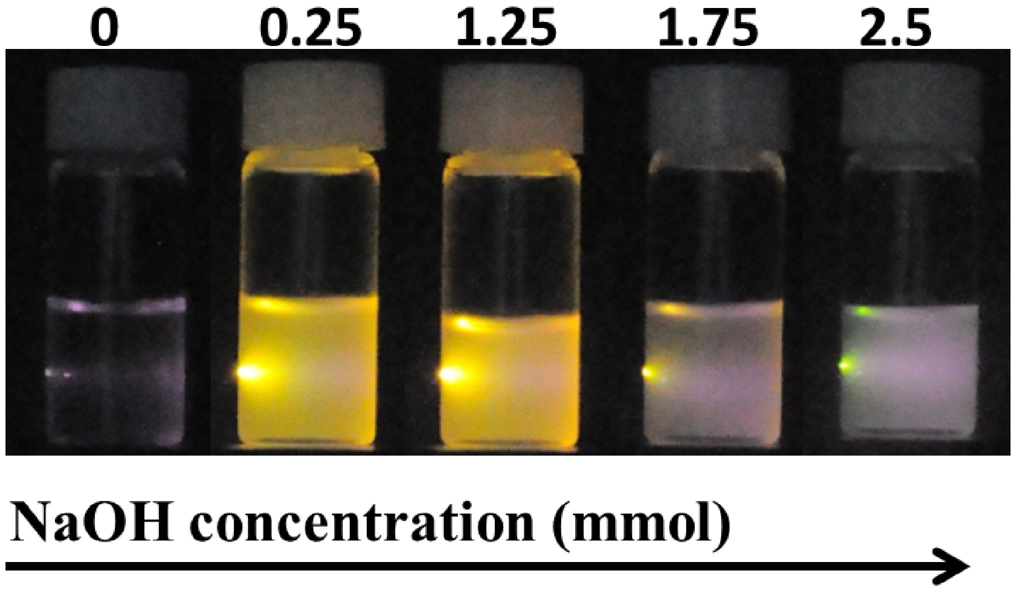

Fig. S11 Luminescent photographs of nanostructures in ethanol solution following excitation at 980 nm with a 360 mW diode laser.

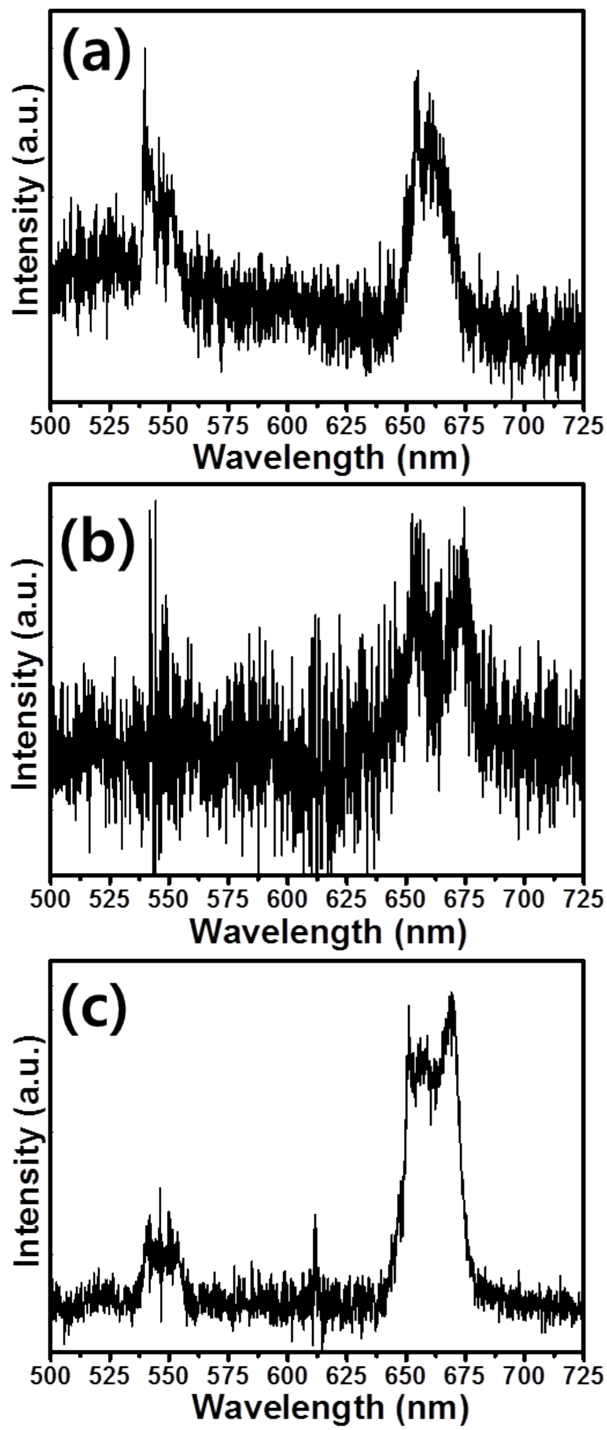

Fig. S12 Upconversion photoluminescence (UC PL) spectra of samples prepared with different surfactant compositions: (a) 100% OA, (b) 1:1 OM/OA mixture, and (c) 1:1 OM/TOP mixture.