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Modified Surface States of $NaGdF_4:Yb^{3+}/Tm^{3+}$ Up-conversion Nanoparticles via a Post-chemical Annealing Process

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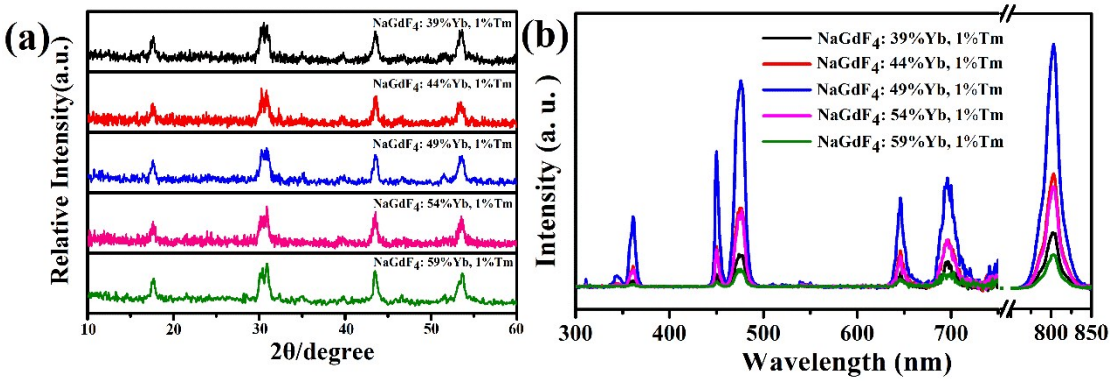

Fig. S1 (a) XRD patterns of $NaGdF_4$: x%Yb^{3+}, 1%Tm^{3+} NPs, (b) the up-conversion spectra of $NaGdF_4$: x%Yb^{3+}, 1%Tm^{3+} NPs under the excitation of 980 nm laser (x= 0.39, 0.44, 0.49, 0.54 and 0.59).

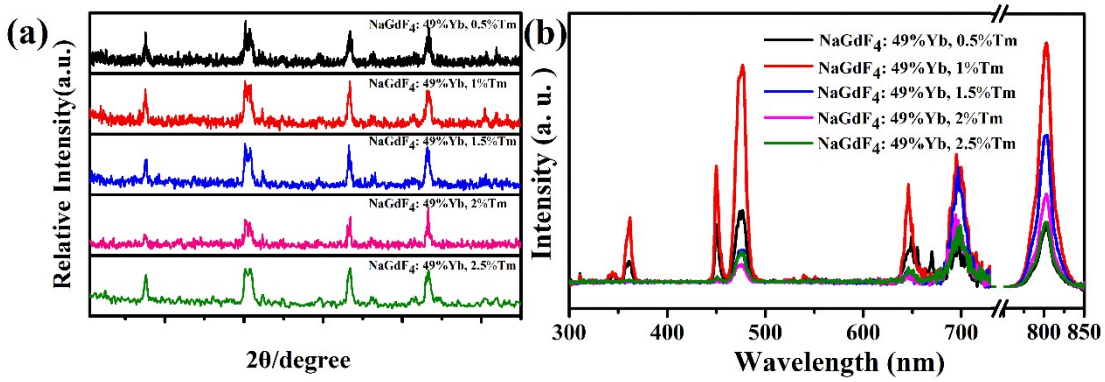

Fig. S2 (a) XRD patterns of $NaGdF_4$: 49%Yb^{3+}, y%Tm^{3+} NPs, (b) the up-conversion spectra of $NaGdF_4$: 49%Yb^{3+}, y%Tm^{3+} NPs under the excitation of 980 nm laser (y= 0.005, 0. 01, 0.015, 0.02 and 0.025).

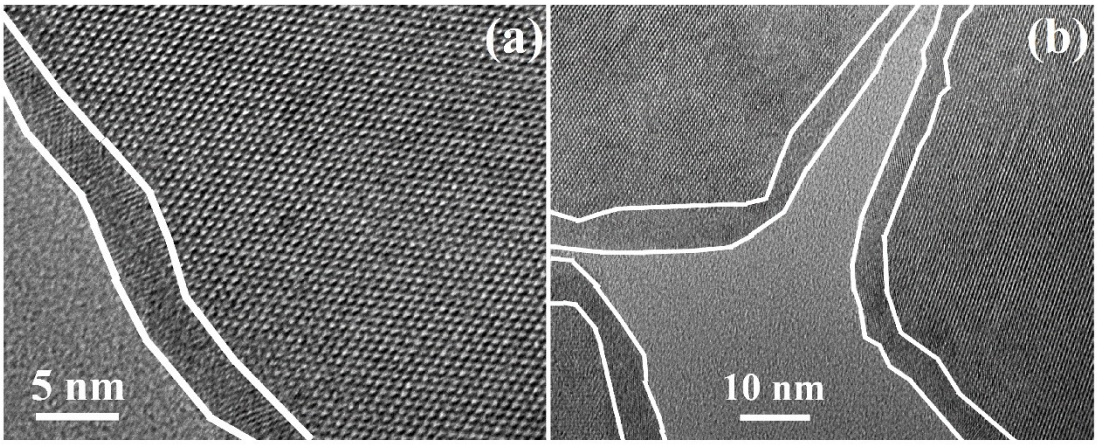

Fig. S3 The HRTEM images of $NaGdF_4$ bare core NPs.

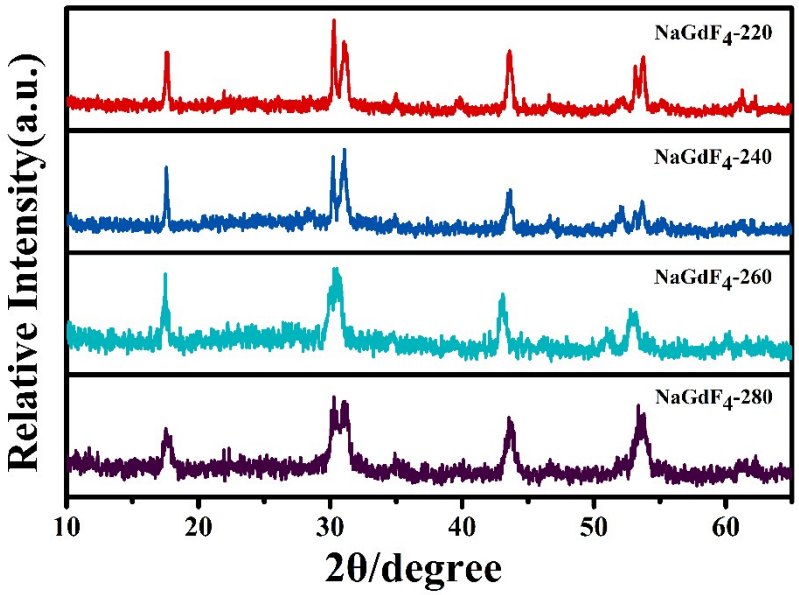

Fig. S4 XRD patterns of the post-chemical annealed $NaGdF_4$: 49%Yb^{3+}, 1%Tm^{3+} NPs at different temperature (T=220, 240, 260, 280℃).

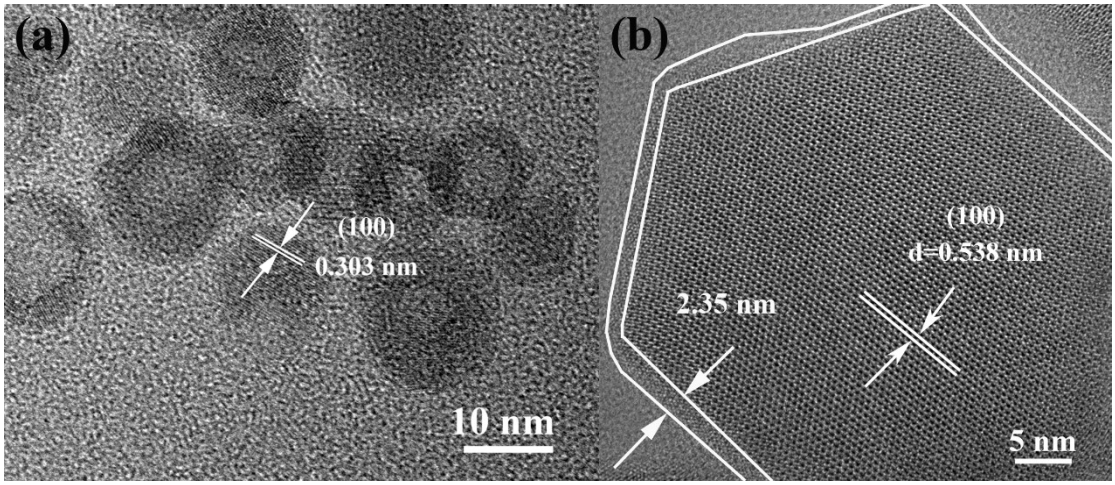

Fig. S5 The HRTEM images of 17-nm (a) and 55-nm (b) NPs after the post-chemical annealing at 200℃.

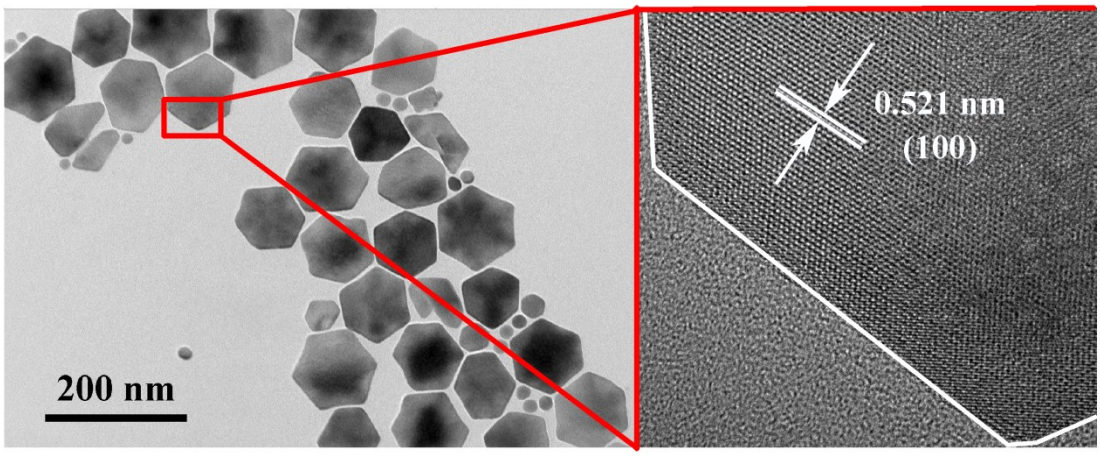

Fig. S6 The TEM (left) and HRTEM (right) images of $NaGdF_4$-260 NPs

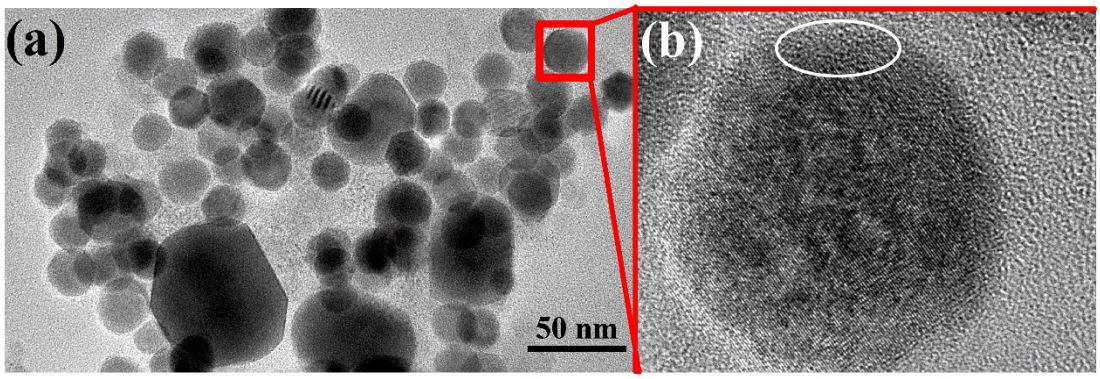

Fig. S7 The TEM (left) and HRTEM (right) images of $NaGdF_4$-280 NPs.

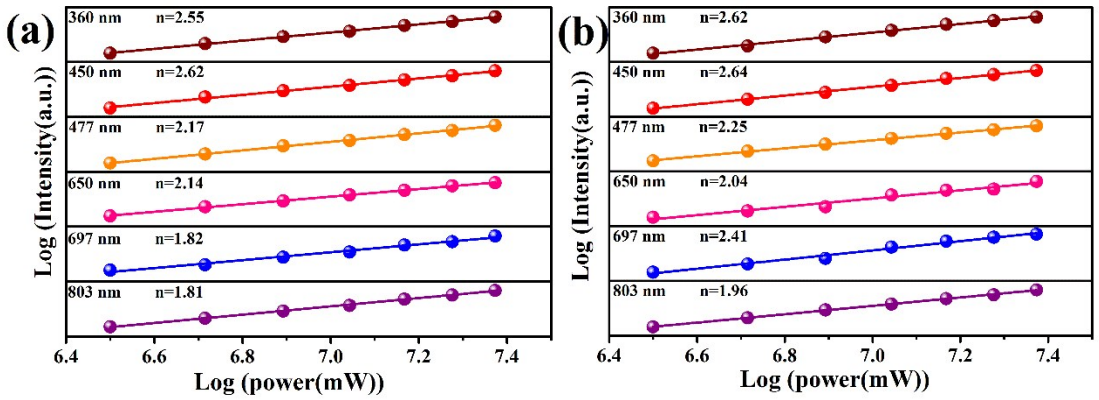

Fig. S8 The logarithmic relationship of Tm^{3+} emission intensities versus power density of $NaGdF_4$ bare core NPs (a) and $NaGdF_4$-250 NPs (b).

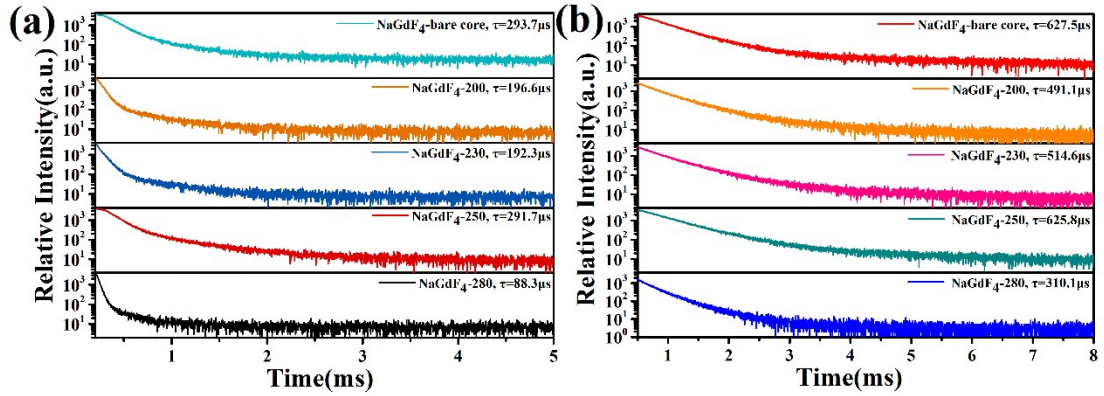

Fig. S9 The fluorescence decay curves of (a) $^3F_{2,3}$ and (b) $^3H_4$ level in $NaGdF_4$ bare core NPs and the post-annealed NPs. (the annealing temperature is 200, 230, 250 and 280℃, respectively.)

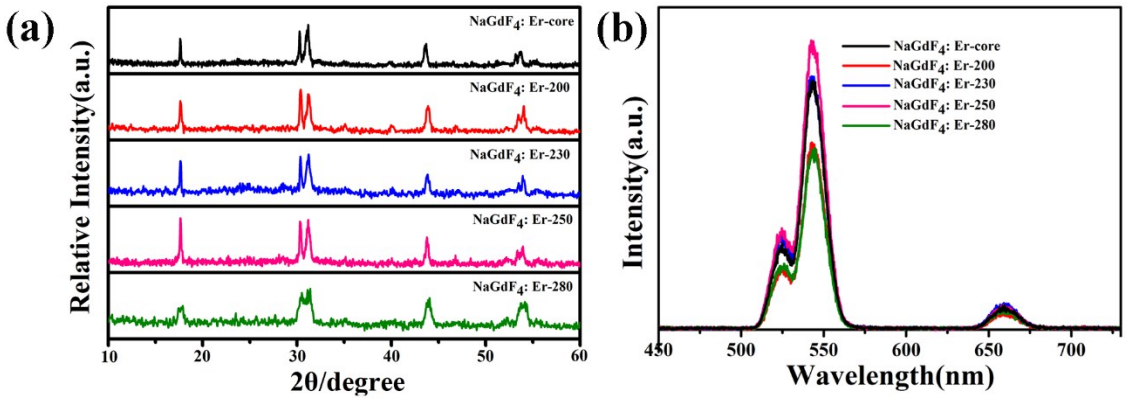

Fig. S10 (a) XRD patterns of $NaGdF_4$: Er^{3+} bare core NPs and the post-annealed NP; (b) The up-conversion spectra of $NaGdF_4$: Er^{3+} bare core NPs and post-annealed NPs under the excitation of 980 nm (the post-chemical annealing temperature is 200, 230, 250 and 280℃, respectively.).

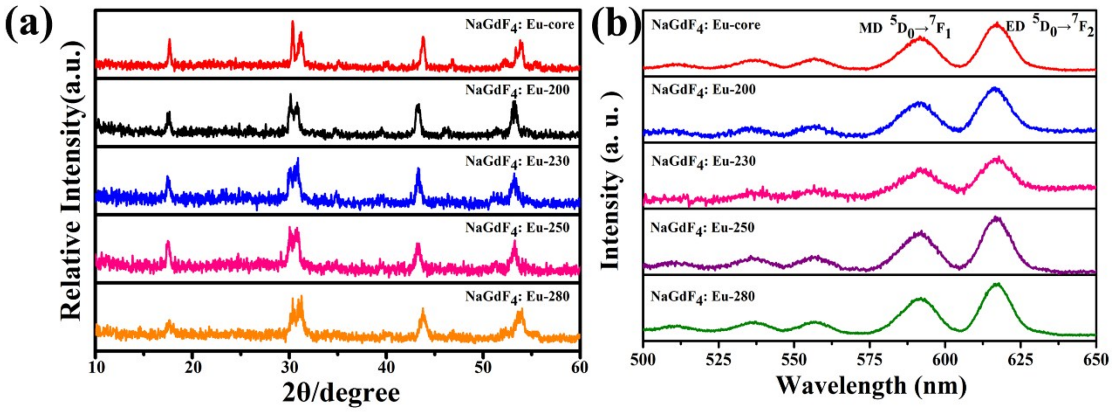

Fig. S11 (a) XRD patterns of $NaGdF_4$: Eu^{3+} bare core NPs and the post-chemical annealed NPs; (b) The down-conversion spectra of $NaGdF_4$: Eu^{3+}bare core and post-annealed NPs under the excitation of 393 nm (the post-chemical annealing temperature is 200, 230, 250 and 280℃, respectively.).

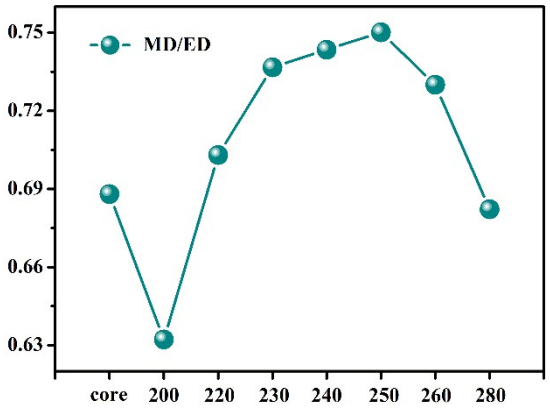

Fig. S12 The intensity ratio of MD/ED of Eu^{3+} as a function of the post-chemical annealing temperature (T=200, 220, 230, 240, 250, 260, 280℃)

Table 1. The color coordinates of $NaGdF_4$ bare core NPs and $NaGdF_4$-250 NPs

Pulse-width(μs)	Bare Core	$NaGdF_4$-250
50	(0.4366, 0.3931)	(0.4234, 0.4009)
100	(0.4263, 0.3889)	(0.4071, 0.3914)
200	(0.4211, 0.3747)	(0.3617, 0.3499)
300	(0.4155, 0.3672)	(0.3233, 0.3186)
400	(0.4045, 0.3580)	(0.2951, 0.2938)
500	(0.3926, 0.3488)	(0.2805, 0.2773)
600	(0.3859, 0.3406)	(0.2660, 0.2595)
700	(0.3758, 0.3324)	(0.2540, 0.2495)
800	(0.3659, 0.3264)	(0.2437, 0.2384)
900	(0.3574, 0.3189)	(0.2401, 0.2335)
1000	(0.3533, 0.3163)	(0.2340, 0.2270)