Electronic Supplementary Material (ESI) for Materials Chemistry Frontiers.

Supporting Information

Multifaceted Luminescence in Lanthanide-Activated Microrods for Advanced Multicolor Anti-Counterfeiting

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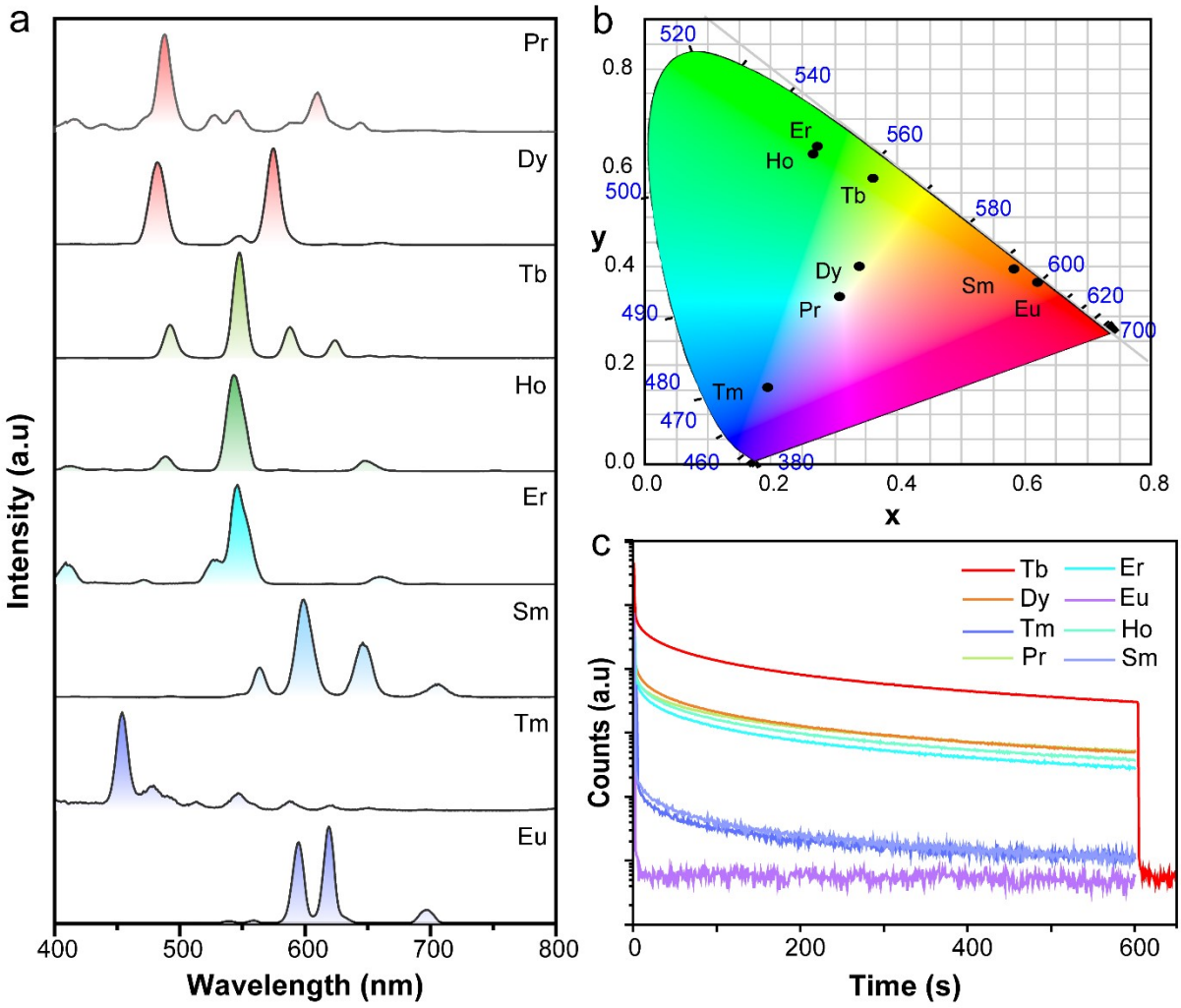

Figure S1. Characterization of persistent luminescence microrods doped with different lanthanide activators. (a) Room-temperature X-ray luminescence spectra of $NaYF_4$: Ln^{3+} (Ln^{3+}=Pr^{3+}, Dy^{3+}, Tb^{3+}, Ho^{3+}, Er^{3+}, Sm^{3+}, Tm^{3+}, Eu^{3+}) microrods. (b) Corresponding Commission Internationale de l'Eclairage (CIE) chromaticity Diagram of persistent luminescence. (c) Room-temperature afterglow decay curves of $NaYF_4$:Ln^{3+} (Ln^{3+}=Pr^{3+}, Dy^{3+}, Tb^{3+}, Ho^{3+}, Er^{3+}, Sm^{3+}, Tm^{3+}, Eu^{3+}) microrods monitored at 488 nm, 575 nm, 546 nm, 544 nm, 546 nm, 599 nm,479 nm, and 618 nm, respectively. Dose rate, 278 μGy s^{-1}; excitation time, 180 s.

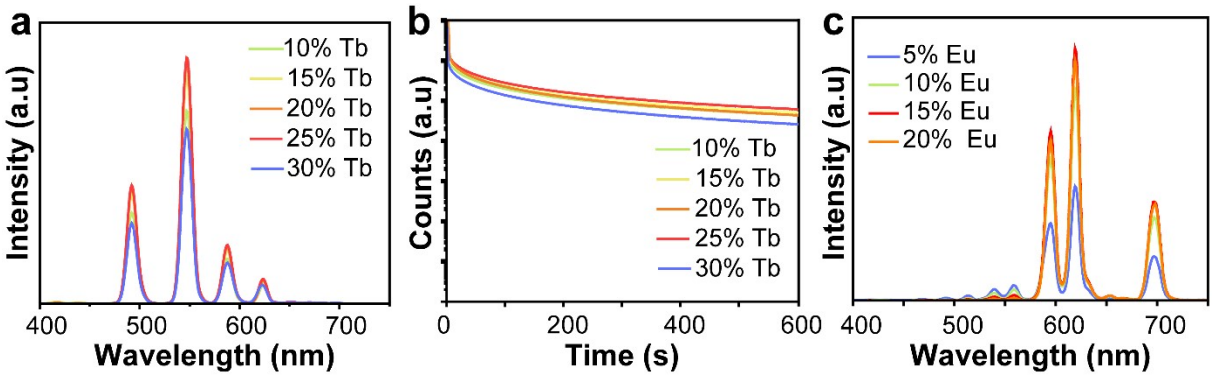

Figure S2. X-ray luminescence spectra (a) and afterglow spectra (b) of $NaYF_4:xTb^{3+}$ microrods doped with different Tb^{3+} contents, (x=10-30 mol%). (c) X-ray luminescence spectra of $NaYF_4:xEu^{3+}$ microrods doped with different Eu^{3+} contents, (x=5-20 mol%).

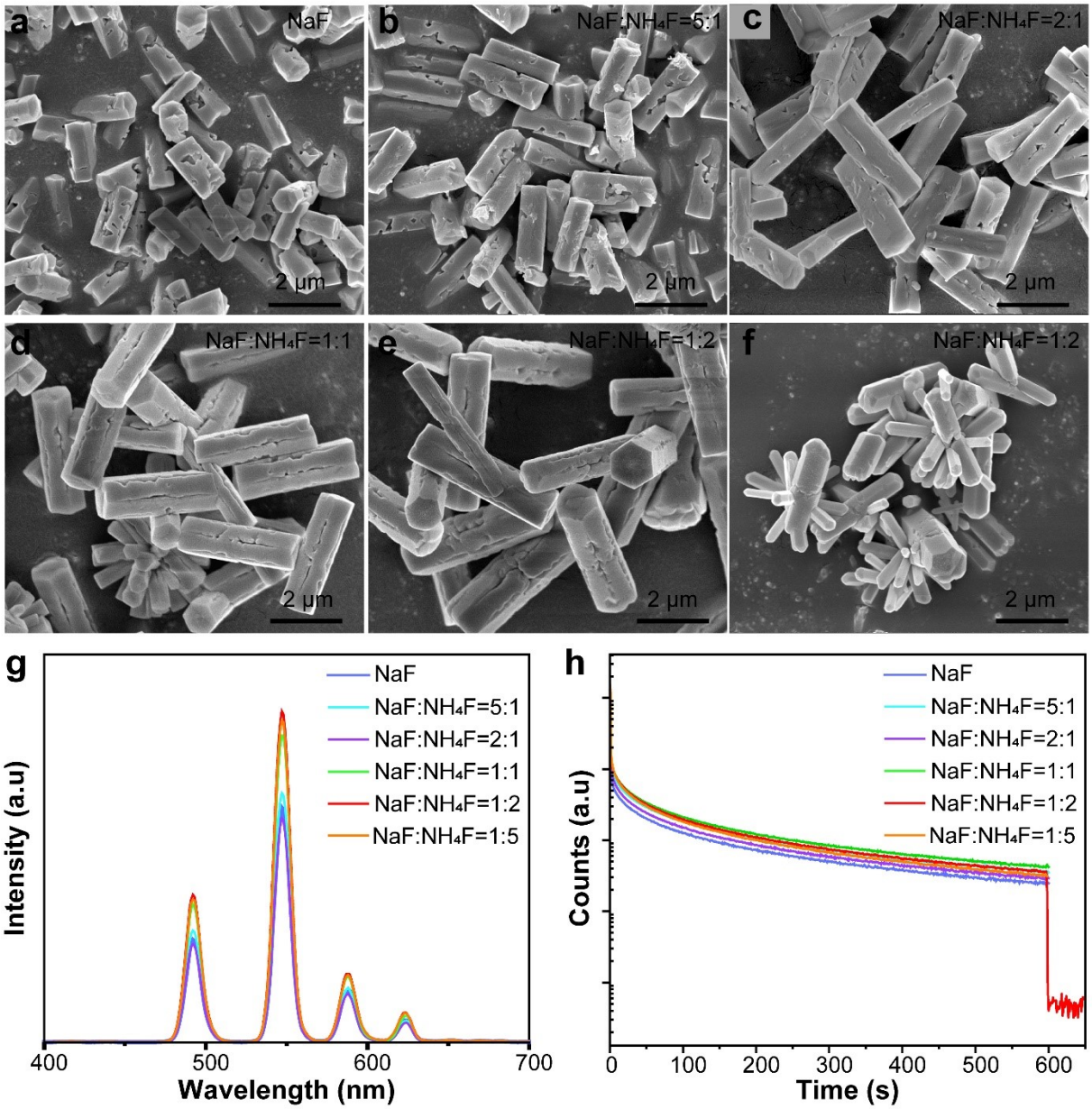

Figure S3. Crystal morphology modulated by F ions. Scanning electron micrographs (a), X-ray luminescence spectra (b), and afterglow spectra (c) of $NaYF_4:Tb^{3+}$ prepared with different ratios of NaF and NH_4F.

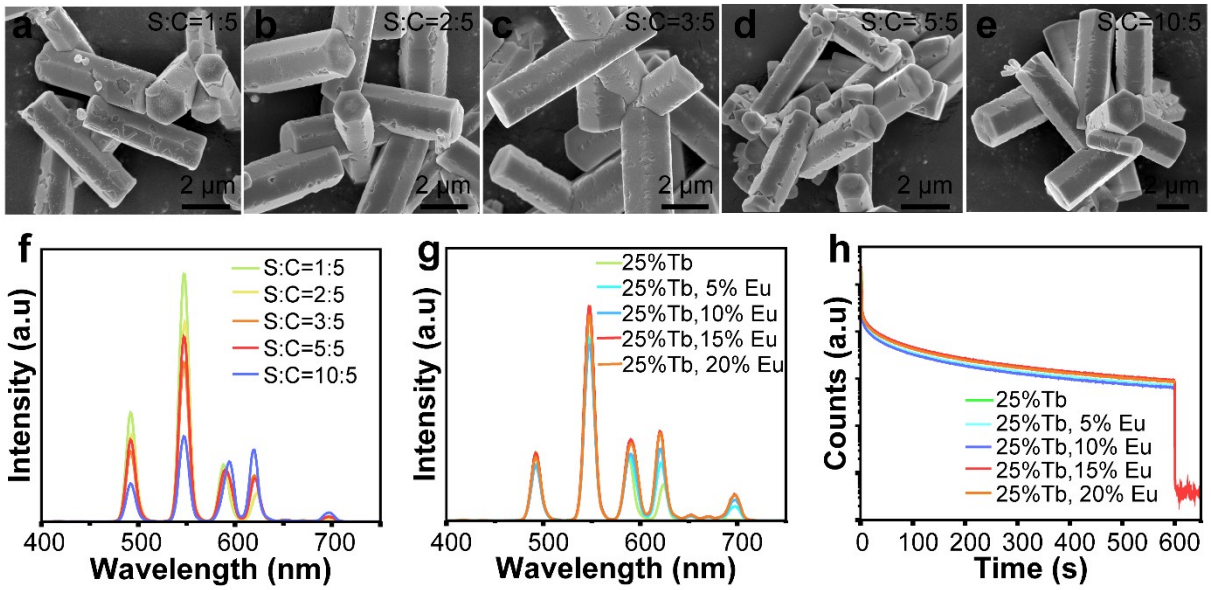

Figure S4. SEM images of microrods grown with various ratios of shell precursor solution (a-e) and the corresponding X-ray luminescence spectra (f). X-ray luminescence spectra (g) and afterglow luminescence spectra (h) of microrods generated by doping various activator concentrations with the same molar shell layer precursor liquid. S:C represents the epitaxial growth precursor to core molar ratio.

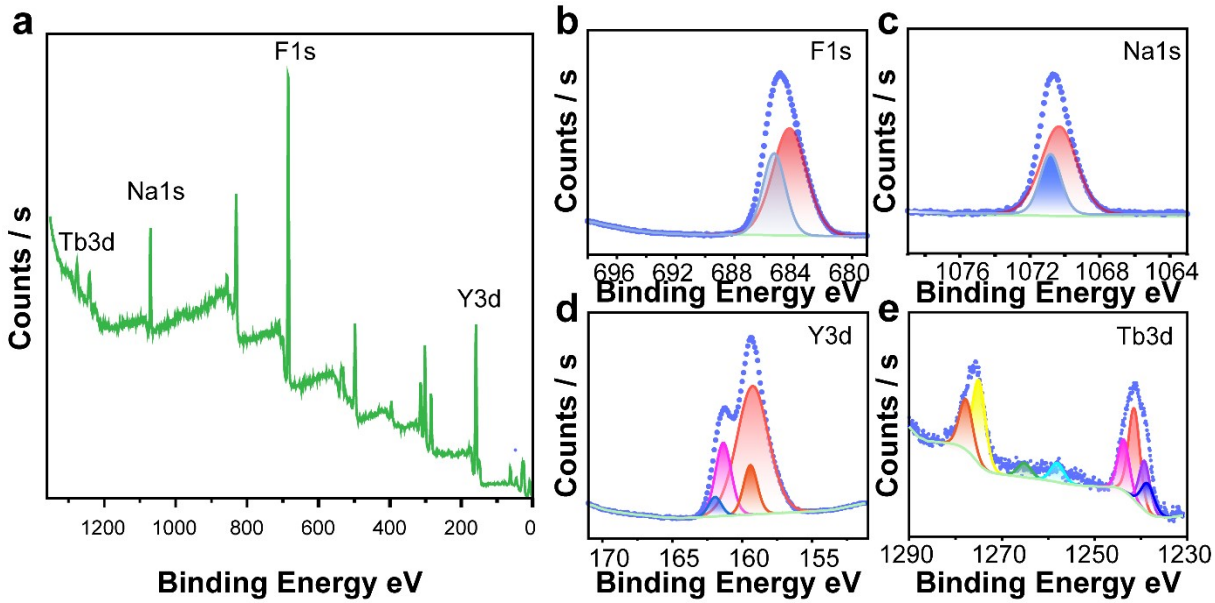

Figure S5. (a) XPS survey spectrum of $NaYF_4$:Tb^{3+}(25 mol%) microrods. High resolution spectra of (b) F, (c) Na, (d) Y, and (e) Tb.

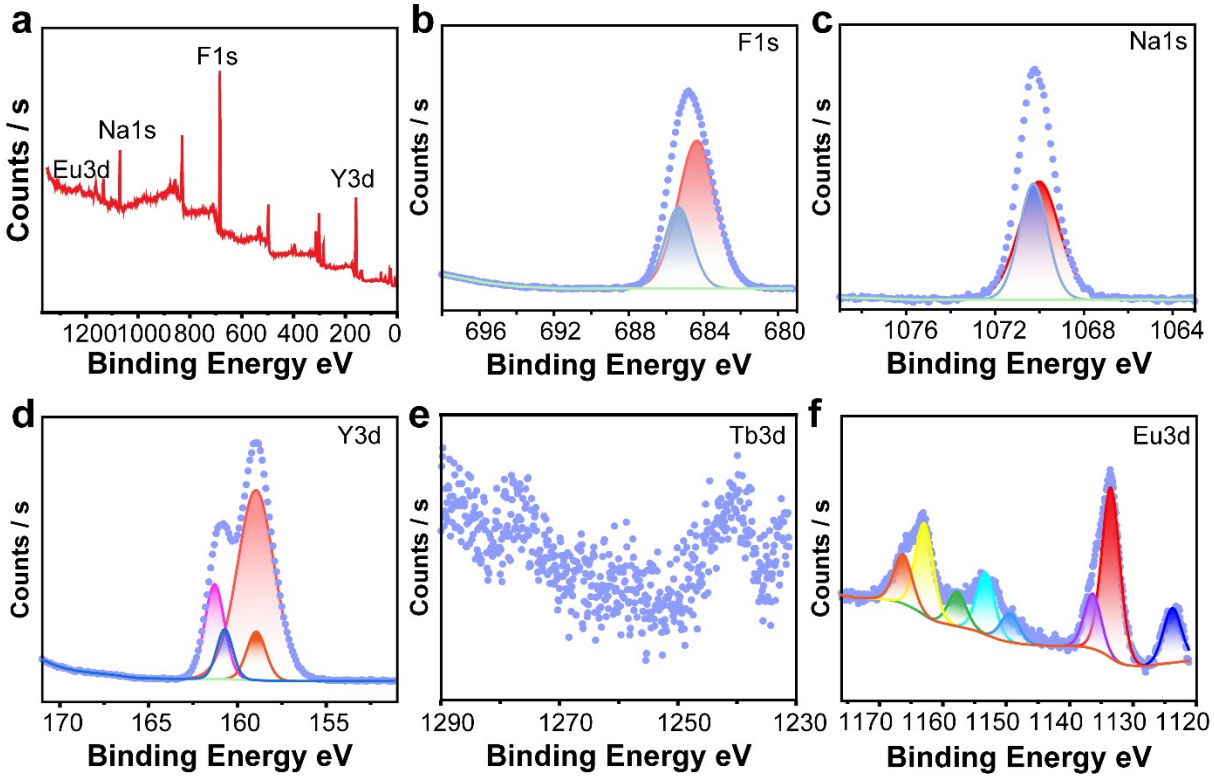

Figure S6. (a) XPS survey spectrum of $NaYF_4$:Tb^{3+}(25 mol%)/$NaYF_4$:Eu^{3+}(15 mol%) microrods. High resolution spectra of (b) F, (c) Na, (d) Y, (e) Tb, and (f) Eu.

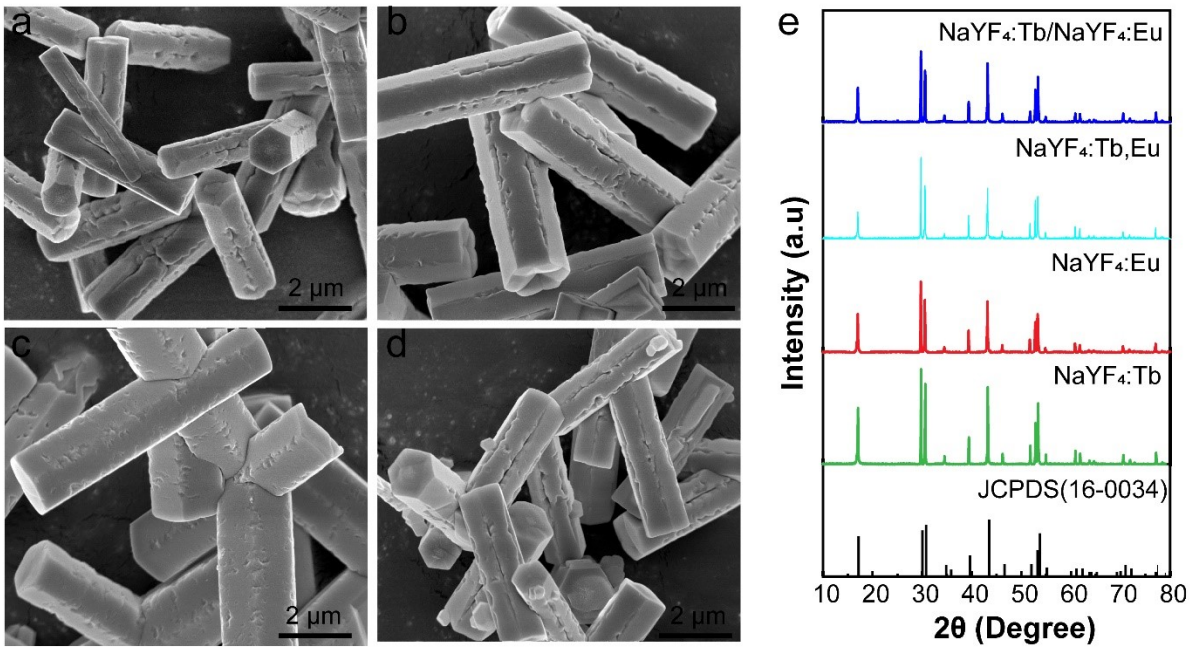

Figure S7. SEM images of (a) $NaYF_4:Tb^{3+}$ (25 mol%), (b) $NaYF_4:Eu^{3+}$ (15 mol%), (c) $NaYF_4:Tb^{3+}$(25 mol%)/$NaYF_4:Eu^{3+}$ (15 mol%), (d) $NaYF_4:Tb^{3+}$, Eu^{3+} (25, 0.5 mol%), and the corresponding X-ray powder diffraction spectrum (e).

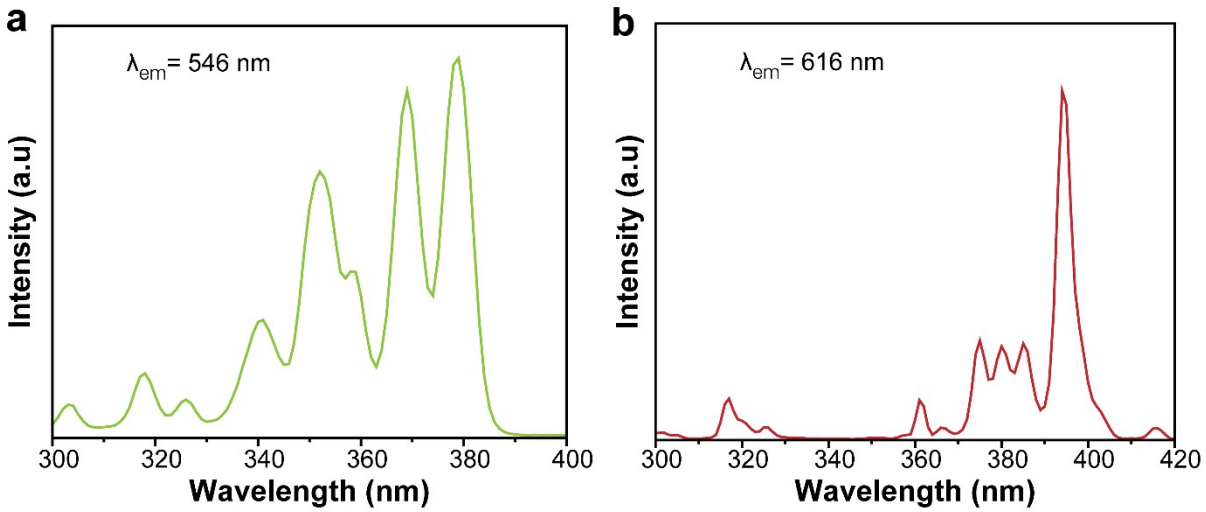

Figure S8. Excitation spectra of $NaYF_4$:Tb^{3+}(25 mol%)/$NaYF_4$:Eu^{3+}(15 mol%). The detection wavelengths were Tb^{3+} 546 nm (a) and Eu^{3+} 616 nm (b).

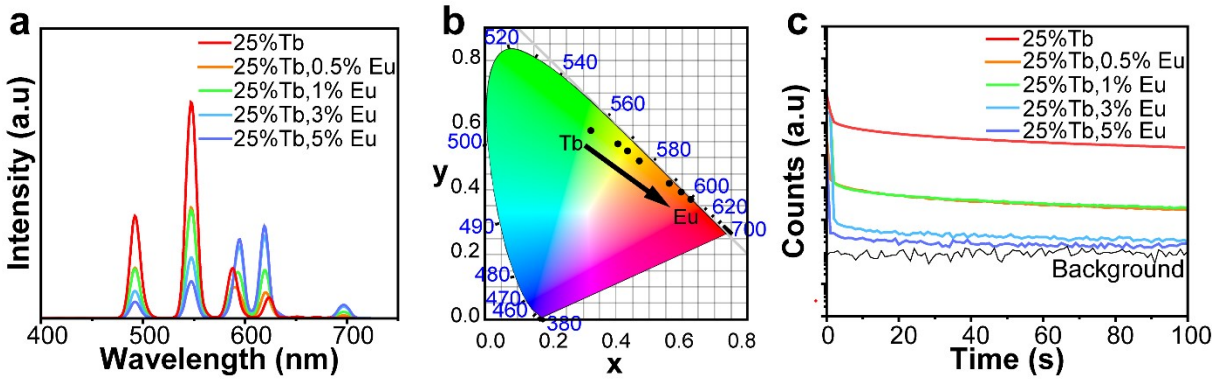

Figure S9. Tunable spectra of $NaYF_4$ co-doped with Tb^{3+} and Eu^{3+}. Controlling for the constant Tb^{3+} content, the Eu^{3+} concentration-dependent of (a) X-ray luminescence spectra, (b) corresponding Commission Internationale de l'Eclairage (CIE) chromaticity diagram, and (c) afterglow spectra.

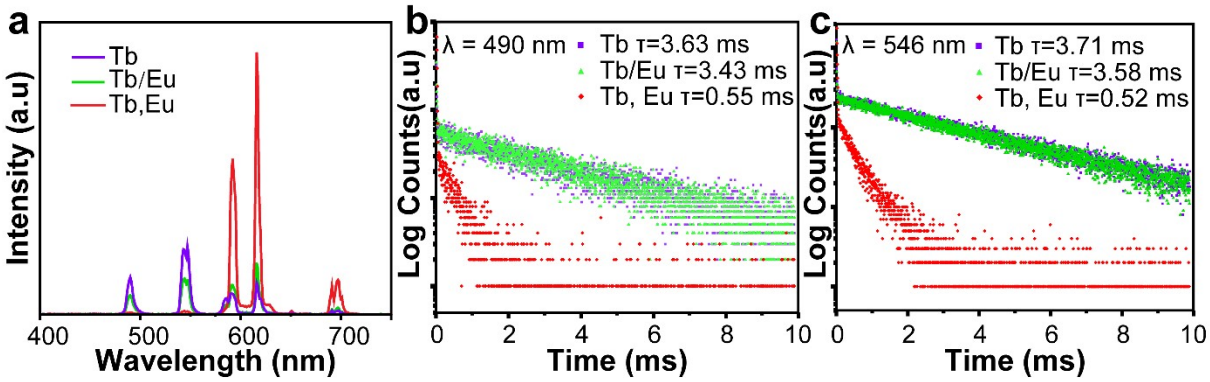

Figure S10. (a) Fluorescence spectra of $NaYF_4:Tb^{3+}$(25 mol%), $NaYF_4:Tb^{3+}$(25 mol%)/$NaYF_4:Eu^{3+}$(15 mol%), and $NaYF_4:Tb^{3+}$, Eu^{3+}(25, 0.5 mol%) under 379 nm excitation. Fluorescence lifetime spectra at 379 nm excitation with detection wavelengths of (b) 490 nm and (c) 546 nm.

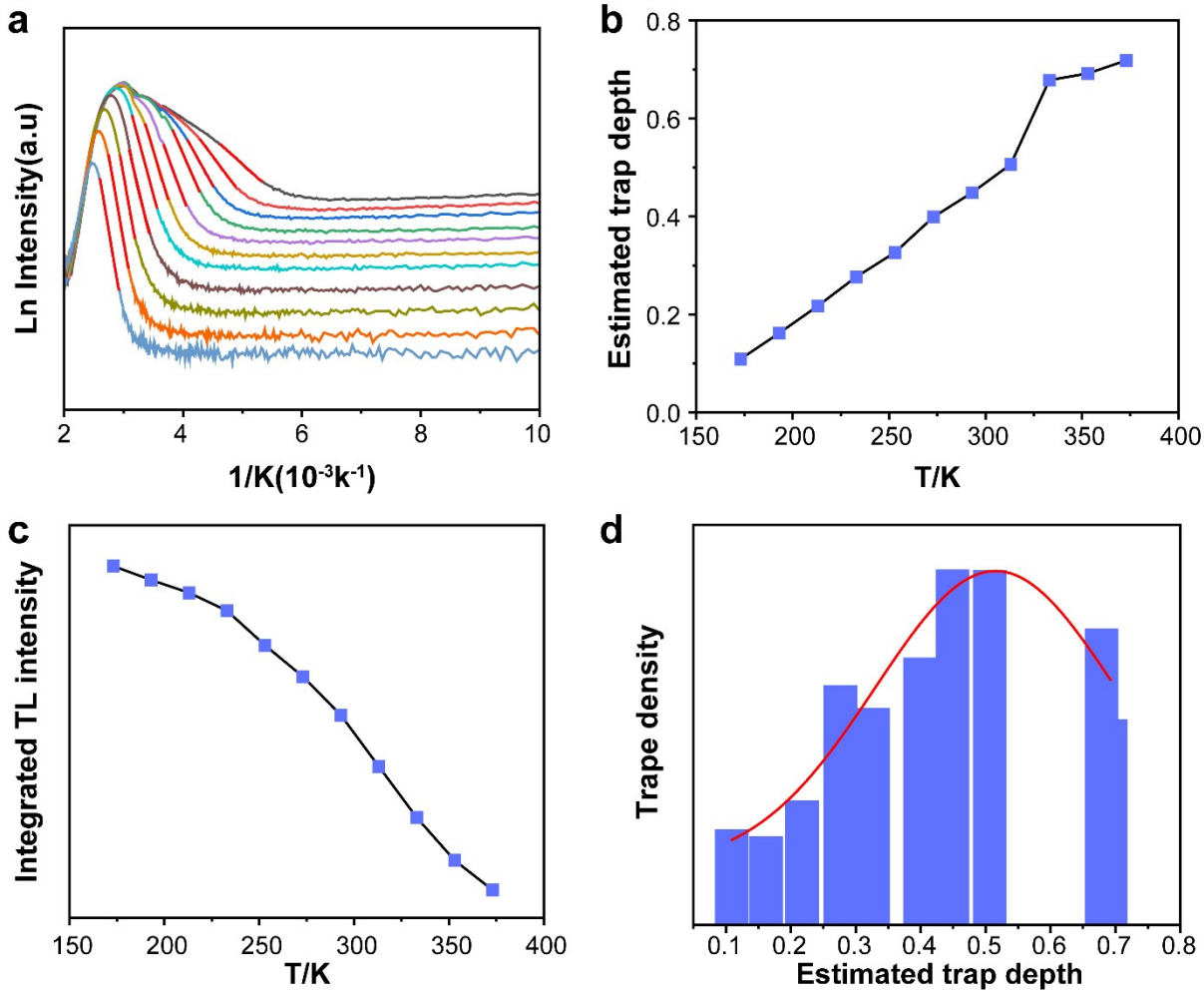

Figure S11. Thermoluminescence curves of $NaYF_4$:Tb^{3+}(25 mol%) microrods tested in the temperature range of 173-373 K. The initial rise method (a) was used to calculate (b) the depth of the defect energy level for each temperature and (c) the integrated area of the peaks of the pyroelectric curve at different excitation temperatures based on the fitted slopes of the thermoluminescence curves. (d) Energy level density for each defect energy level.

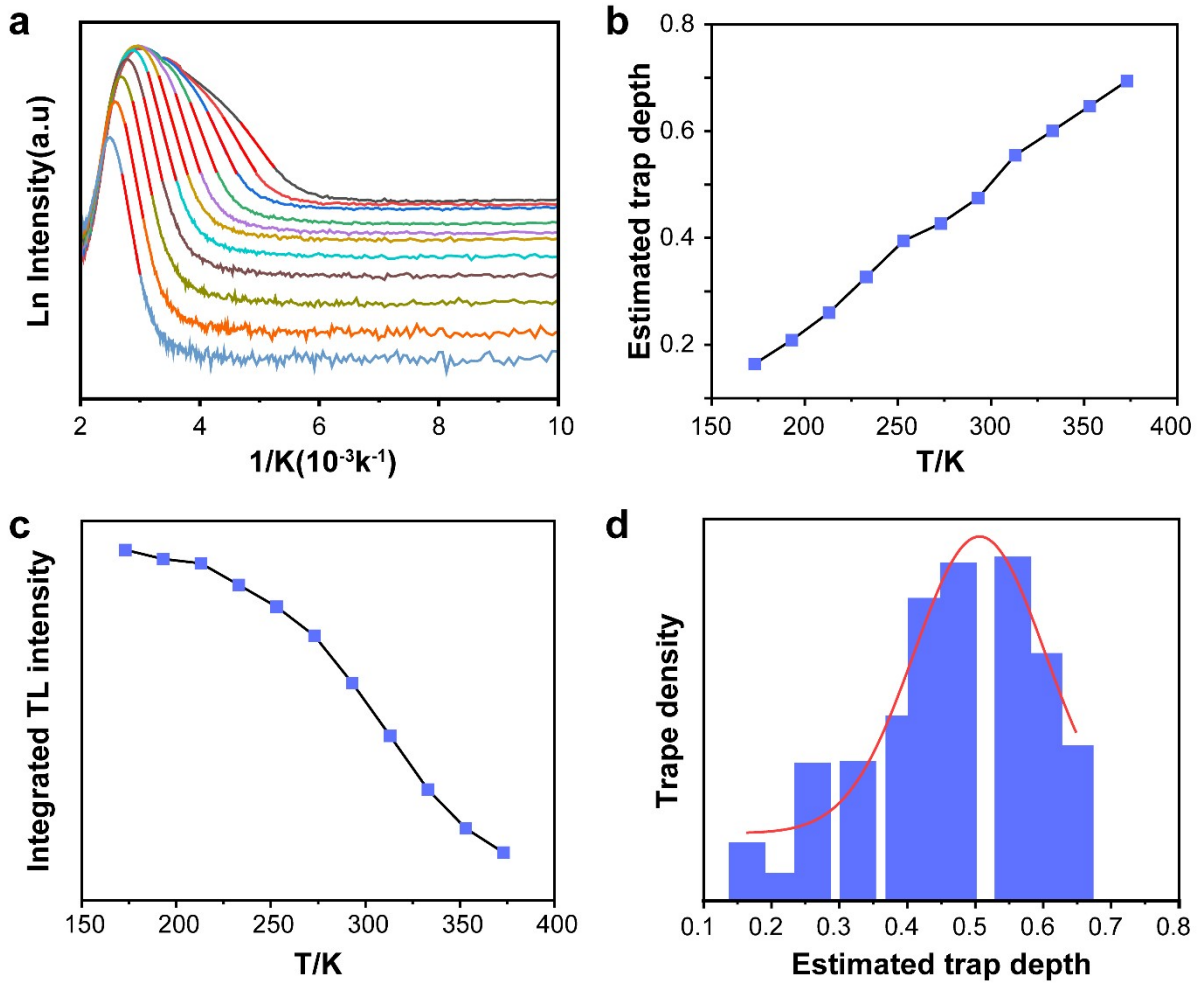

Figure S12. Thermoluminescence curves of $NaYF_4$:Tb^{3+}(25 mol%)/$NaYF_4$:Eu^{3+}(15 mol%) microrods tested in the temperature range of 173-373 K. The initial rise method (a) was used to calculate (b) the depth of the defect energy level for each temperature and (c) the integrated area of the peaks of the pyroelectric curve at different excitation temperatures based on the fitted slopes of the thermoluminescence curves. (d) Energy level density for each defect energy level.