

Supporting Information

Strong green upconversion emission from submicron spindle-shaped SrMoO₄:Yb³⁺,Er³⁺

Thulitha M. Abeywickrama and Yuanbing Mao*

Department of Chemistry, Illinois Institute of Technology, 3105 South Dearborn Street, Chicago,
IL 60616, USA

*To whom correspondence should be addressed. Email: ymao17@iit.edu, Tel.: +1-312-567-3815

Solid state sample preparation for SrMoO₄:1Yb³⁺,1Er³⁺

Solid state SrMoO₄:1% Yb³⁺,1%Er³⁺ were prepared modified solid-state reaction. For this purpose SrCO₃, MoO₃, Yb₂O₃ (from Sigma-Aldrich), and Er(NO₃)₃ (from Alfa Aesar) of high purity (99.9+%) in stoichiometric proportions were mixed in a mortar for and ground for 30 minutes. The initial calcination step was carried out at 350°C for 3 h, and the powder mixture was then ground again for 30 minutes and further sintered at 950°C for 6 h. The XRD pattern and SEM of the as-prepared sample is provided in Figure S5 below.

Particle size from Scherrer equation

$$D = \frac{K\lambda}{\beta \cos\theta}$$

D = particle size (nm)
 K = Scherrer constant (0.9)
 λ = wavelength of X-ray source (0.15406)
 β = FWHM (radian)
 θ = peak position (radian)

Time/h	Average Particle size (nm)
4	26.1 ± 5.5
6	26.4 ± 6.03
7	22.2 ± 8.04
10	26.2 ± 5.21
24	25.5 ± 6.08

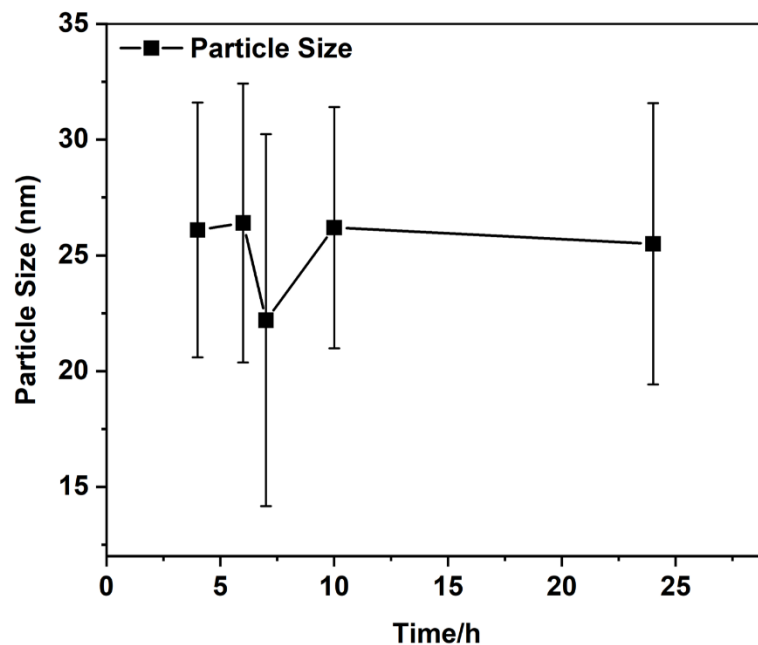


Figure S1. Particle/grain size calculation from FWHM of XRD peaks using the Scherrer equation of SMO doped with 1% Yb³⁺ and 1% Er³⁺ synthesized at different HT reaction times. Average particle size is presented along with the standard deviation for each calculation.

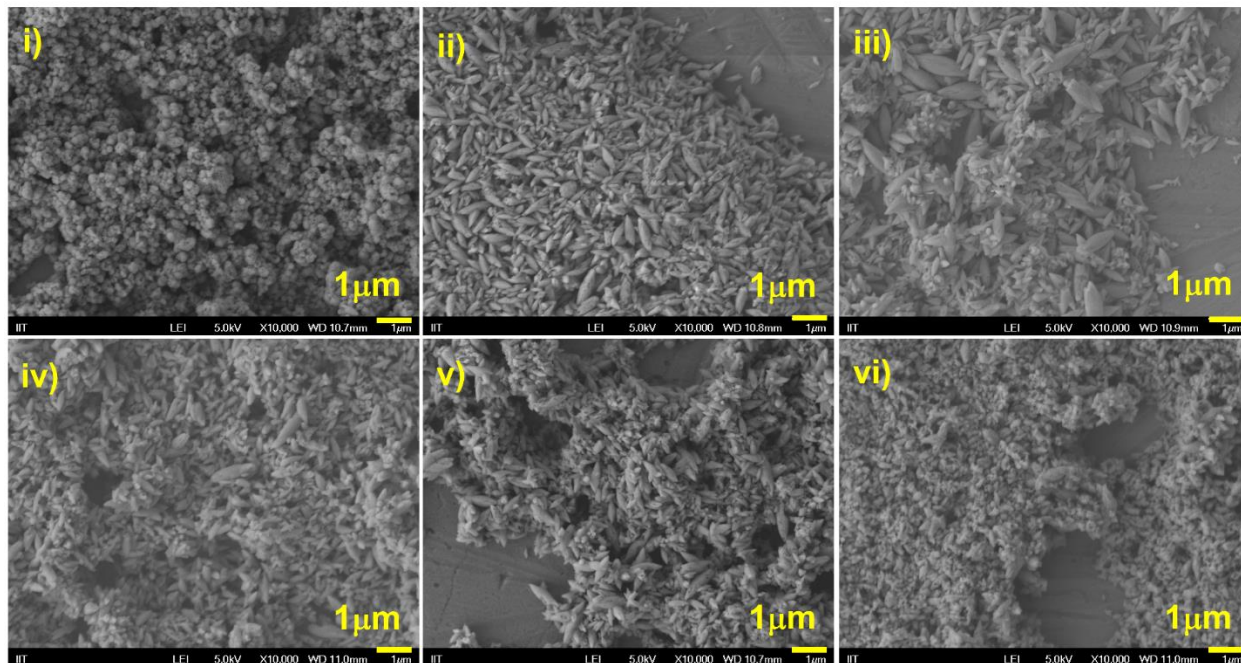


Figure S2. FE-SEM images of the SMO samples doped with 1% Yb^{3+} and 1% Er^{3+} as synthesized at different pH conditions: (i) pH 7, (ii) pH 8, (iii) pH 9, (iv) pH 9.5, (v) pH 10, and (vi) pH 11.

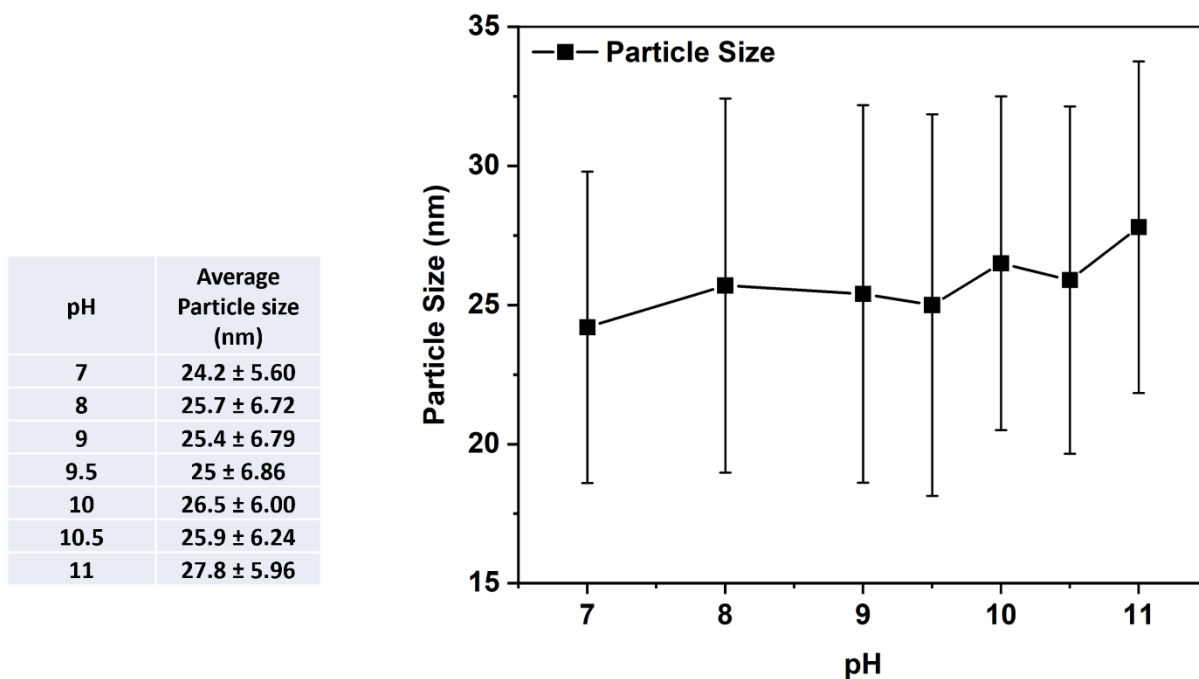


Figure S3. Particle size calculation from FWHM of XRD peaks using Scherrer equation of SMO doped with 1% Yb^{3+} and 1% Er^{3+} synthesized at different pH conditions. Average particle size is presented along with the standard deviation for each calculation.

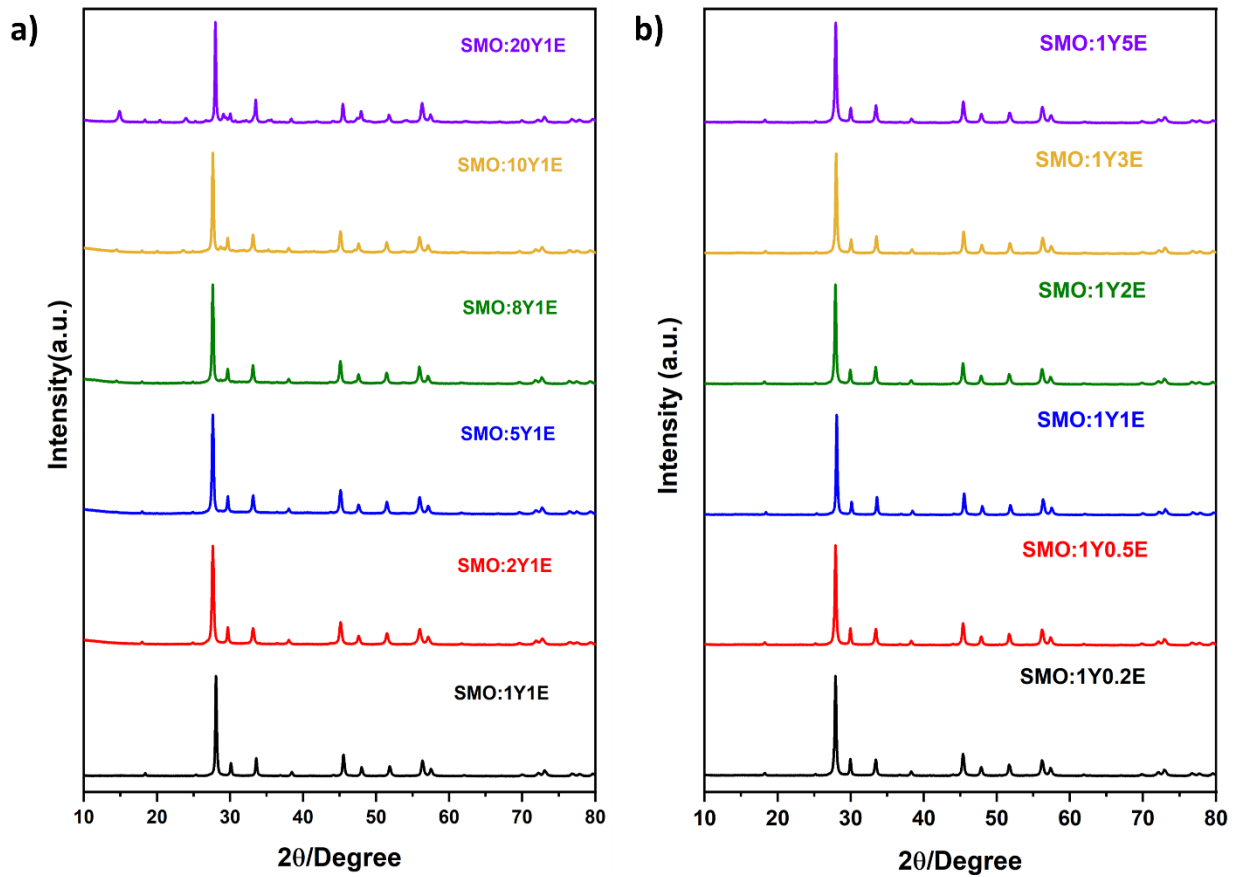


Figure S4. XRD patterns of SrMoO₄:x%Y³⁺,y%Er³⁺ samples with varying Yb³⁺ and Er³⁺ doping levels: (a) x = 1, 2, 5, 8, 10, 20 with y = 1%. (b) y = 0.2, 0.5, 1, 2, 3, and 5 with x = 1%.

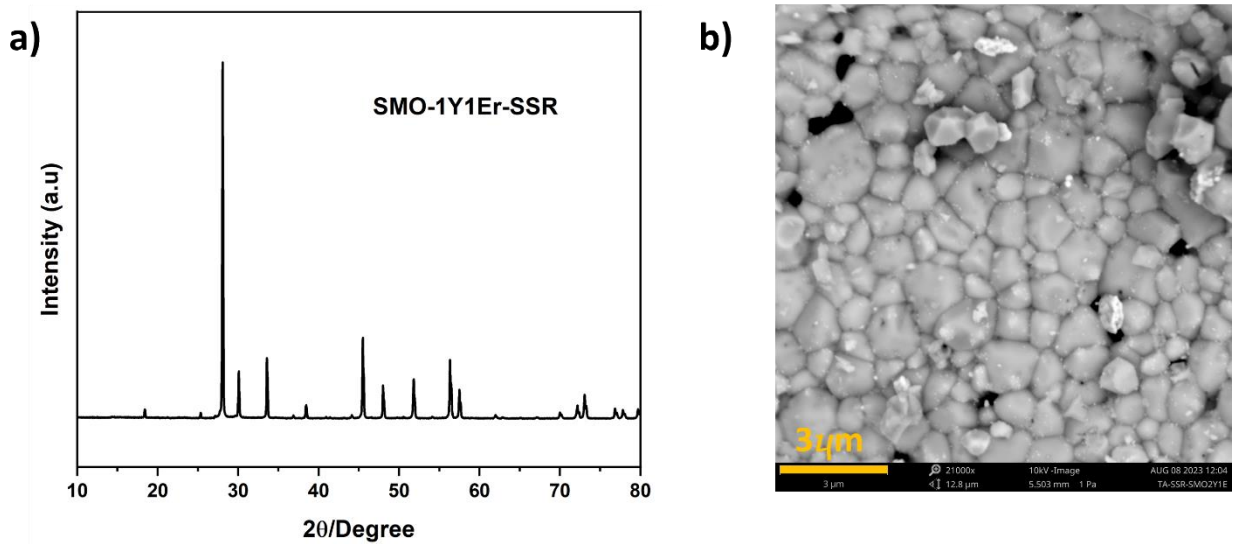


Figure S5. Solid state synthesized SMO-1Y1Er: (a) XRD pattern. (b) SEM image.

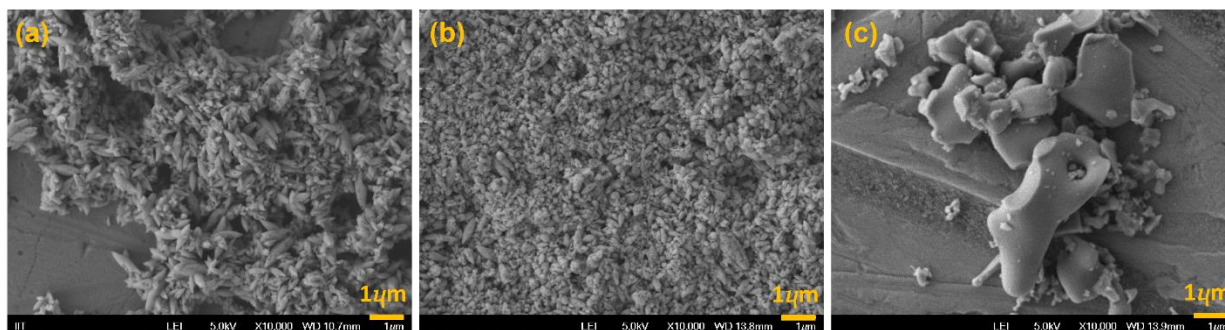


Figure S6. FE-SEM images of our hydrothermally synthesized SMO sample doped with 1% Yb^{3+} and 1% Er^{3+} (a) before and (b) after molten salt annealing at 500°C for 6 h. (c) Commercial $\text{NaYF}_4:\text{Yb,Er}$ sample.

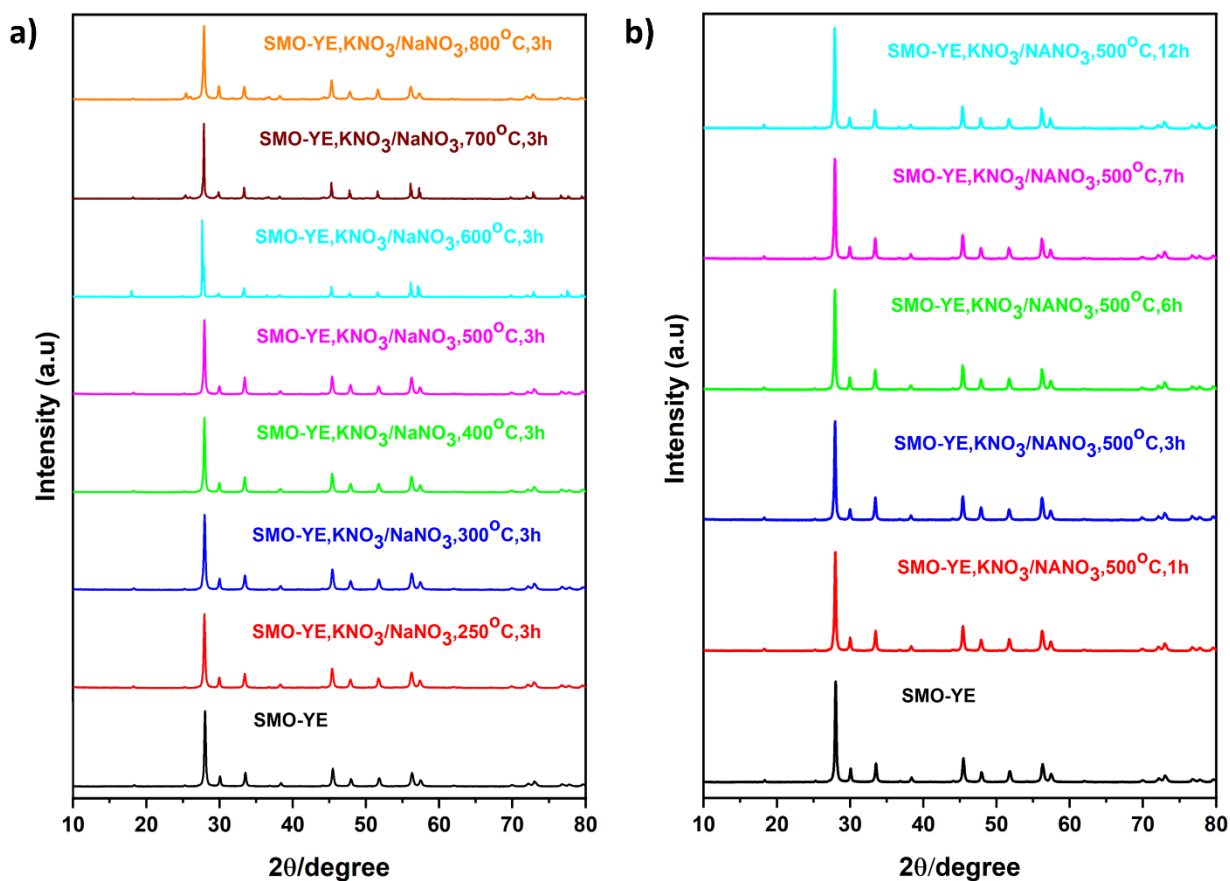


Figure S7. XRD patterns of $\text{SrMoO}_4:1\% \text{Y}^{3+}, 1\% \text{Er}^{3+}$ samples with varying annealing temperature and annealing time in $\text{KNO}_3/\text{NaNO}_3$ salt mixture. (a) Annealing temperature. (b) Annealing time.

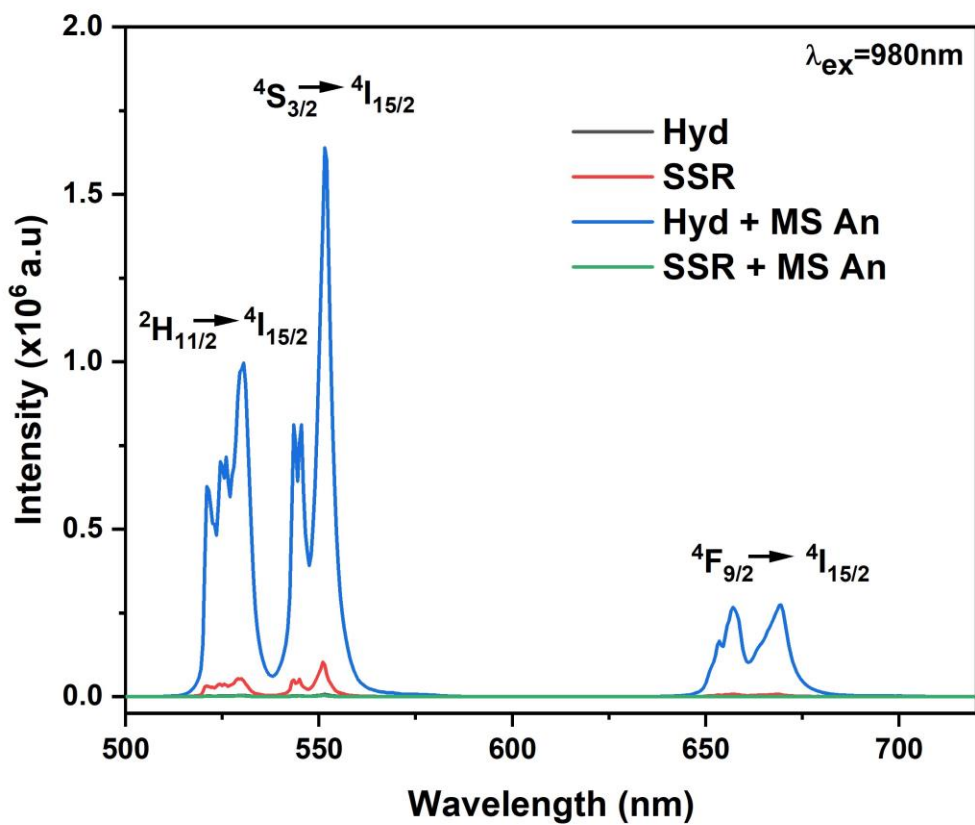


Figure S8. Upconversion emission comparison of hydrothermally produced (Hyd), solid state synthesized (SSR), hydrothermally produced followed by molten salt annealed for 500°C, 6h (Hyd+MS An) and solid state synthesized followed by molten salt annealed for 500°C,6h (SSR+MS An) samples of SMO doped with 1% Yb³⁺ and 1% Er³⁺.

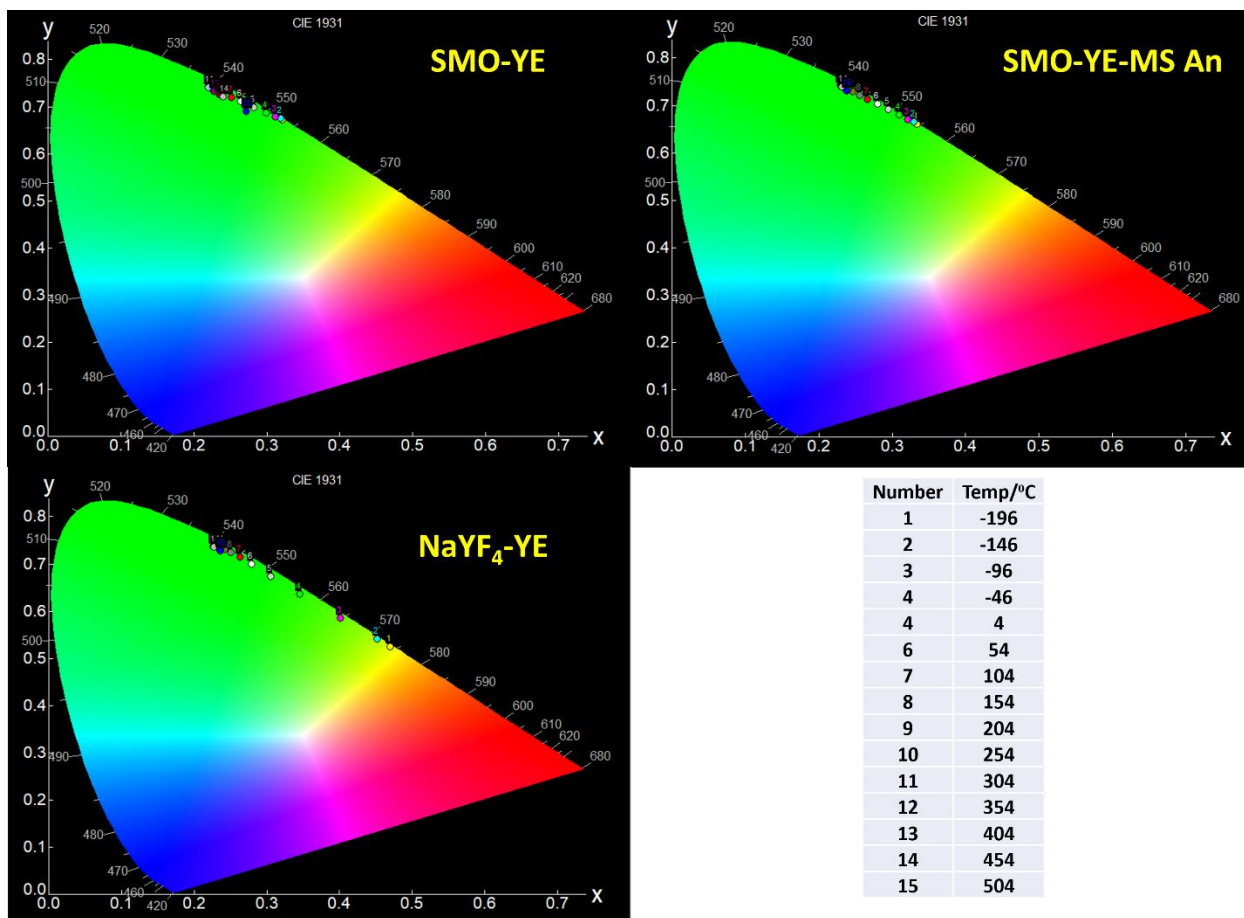


Figure S9. CIE color coordinates variation (CIE 1931) with temperature for hydrothermally produced (SMO-YE), molten salt annealed (SMO-YE-MS An) and NaYF₄:20% Yb³⁺, 3% Er³⁺ (NaYF₄-YE) samples.

Table S1. Composition of elements in SrMoO₄ doped with 1% Yb³⁺ and 1% Er³⁺ by EDS

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
8	O	Oxygen	72.55	31.52
42	Mo	Molybdenum	14.02	36.54
38	Sr	Strontium	13.43	31.94