

Supporting Information

A Cooperative Afterglow Enhancement in Second Biological Window of $\text{Na}_2\text{CaSn}_2\text{Ge}_3\text{O}_{12}$ with Co-doping of Pr^{3+} - Yb^{3+}

Xiuping Gao^{*abc}, Tao Liu^a, Xiaohui Jiang^a, Kai Huang^c, Runlin Liu^a, Jinyuan Zhou^a, Erqing Xie^a, Yang Li^d, Weisheng Liu^b, Min Wang^{*c}, Gang Han^{*c}

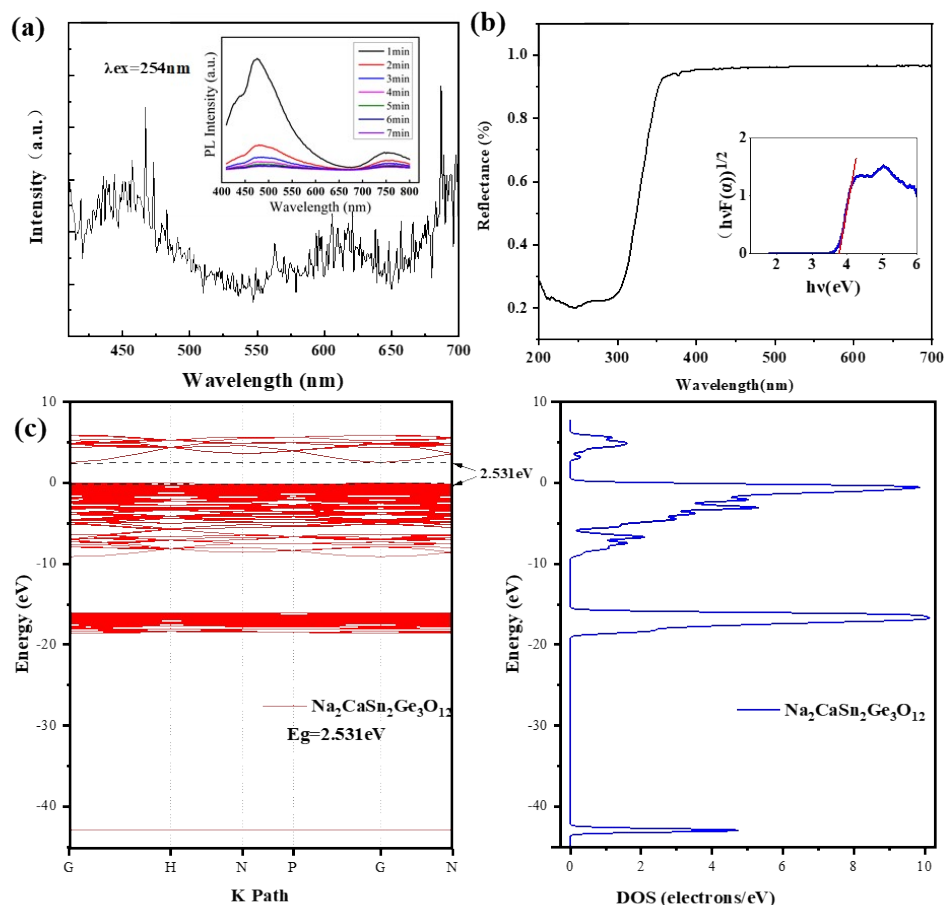


Figure S1. (a) PL spectra of NCSGO excited at 254nm, inset is the LPL decay spectra of NCSGO at different decay times, (b) DRS test result of NCSGO, (c) Band gap of NCSGO calculated according to density functional theory.

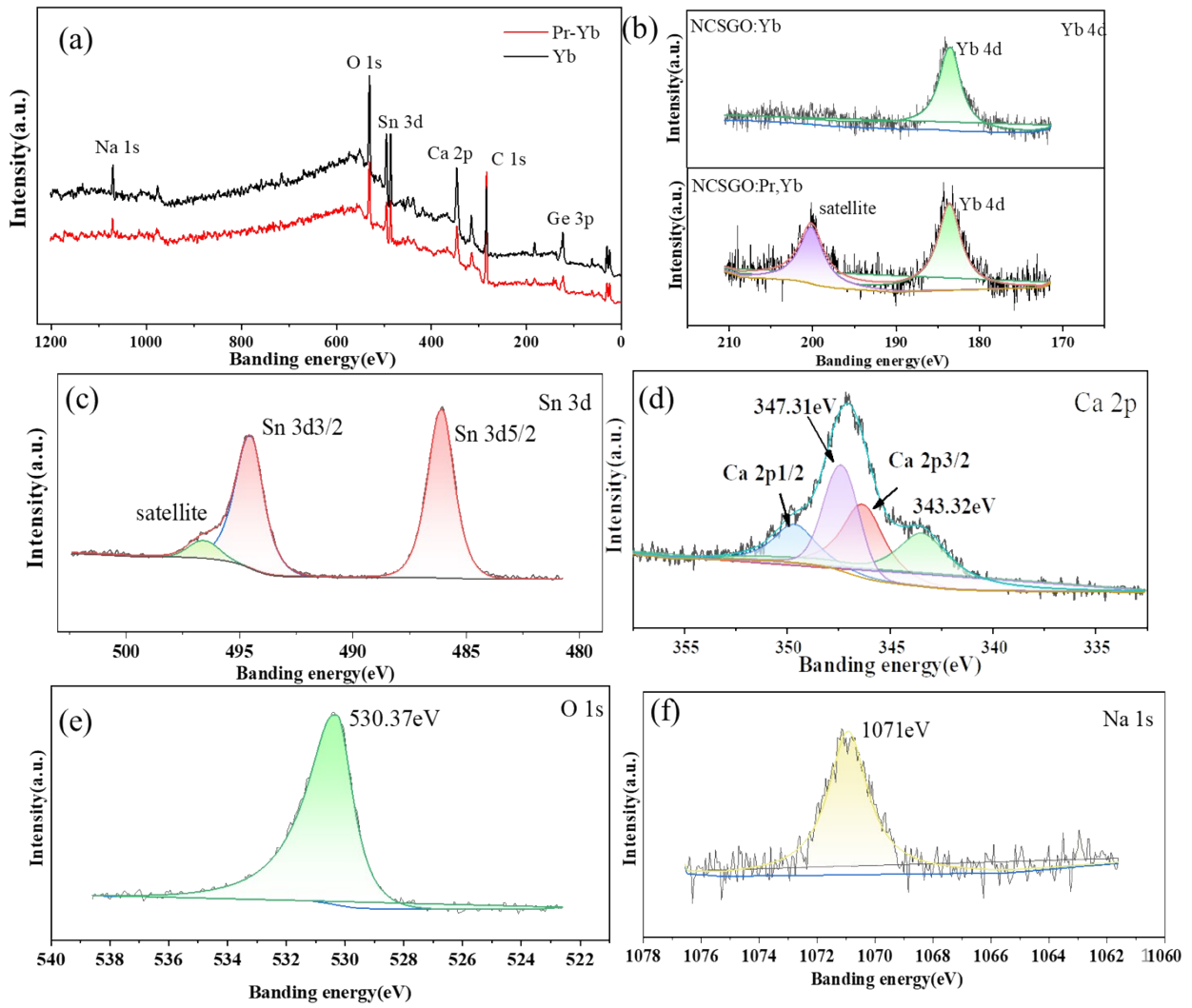


Figure S2. (a) XPS survey wide scan spectrum of NCSGO: 0.8%Yb³⁺ and NCSGO: 0.8%Pr³⁺, 0.8%Yb³⁺, (b) XPS narrow scan spectrum of Yb4d of NCSGO: 0.8%Yb³⁺ and NCSGO: 0.8%Pr³⁺, 0.8%Yb³⁺, (c-f) XPS narrow scan spectrum of Sn3d, Ca2p, O1s and Na1s of NCSGO: 0.8%Pr³⁺, 0.8%Yb³⁺.

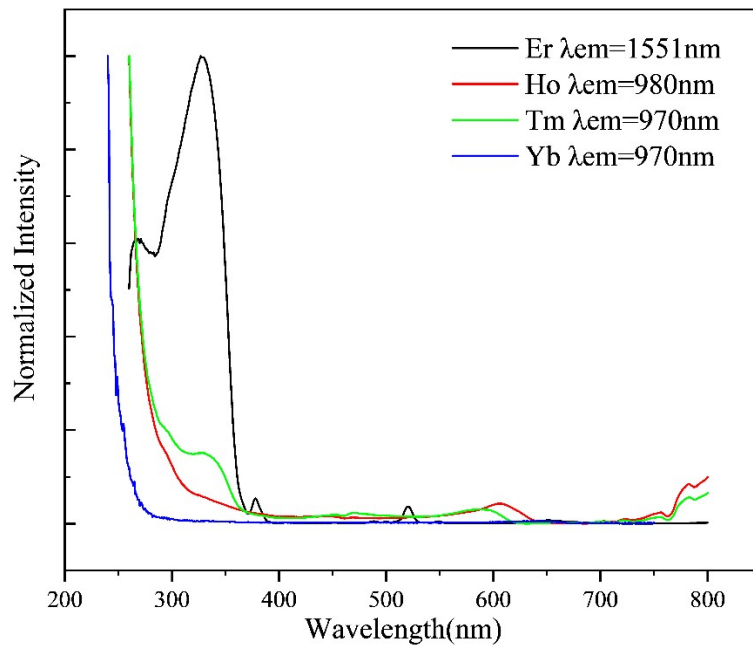


Figure S3. PLE spectra of NCSGO: RE³⁺, RE³⁺ = Tm³⁺, Er³⁺, Yb³⁺, Ho³⁺.

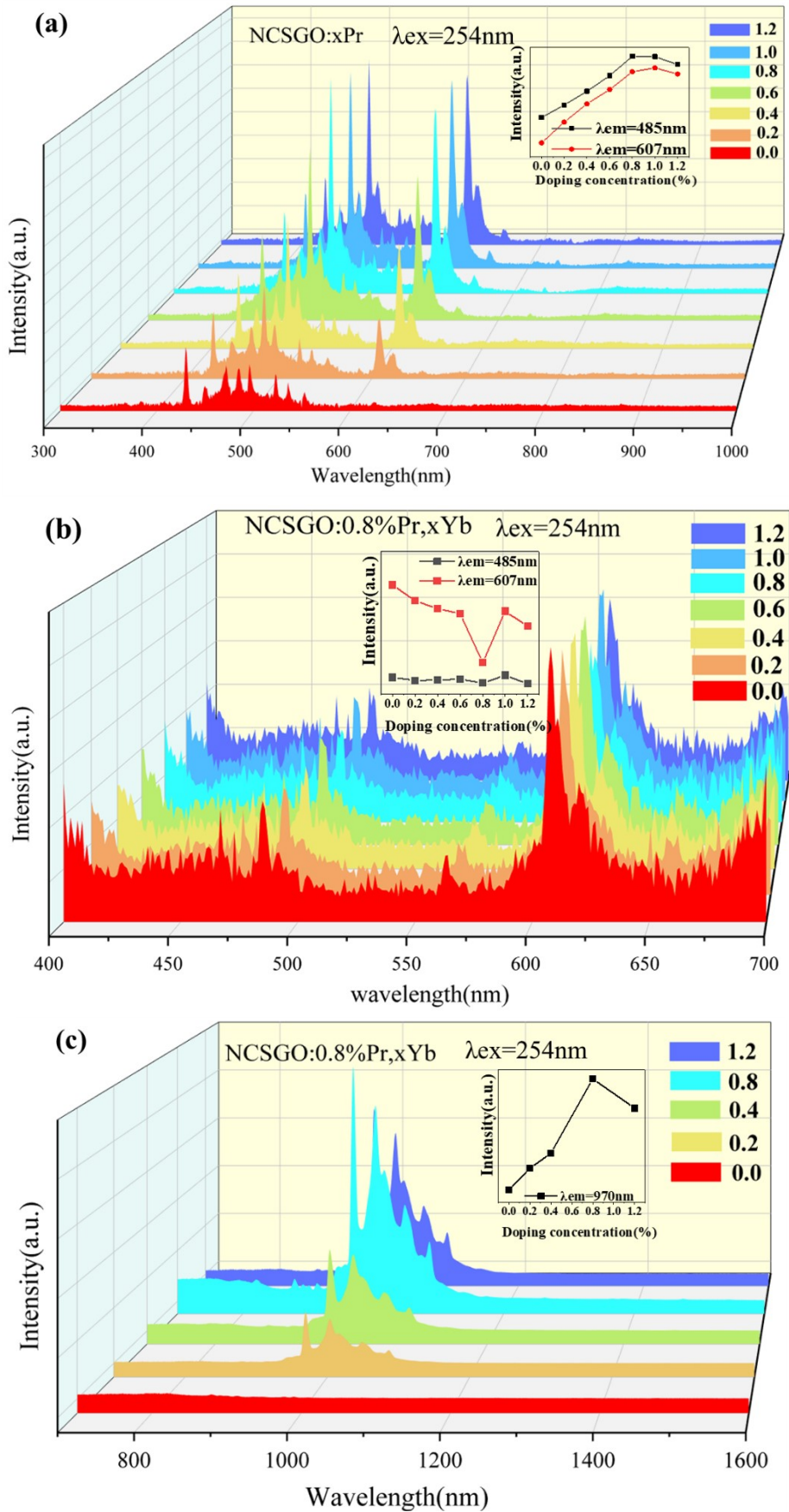


Figure S4. (a) The PL spectra of NCSGO: x%Pr ($0 \leq x \leq 1.2$), (b-c) PL spectra of NCSGO: 0.8%Pr, x%Yb ($0 \leq x \leq 1.2$), the insets are the emission peaks intensity curves as a function of doping concentration.

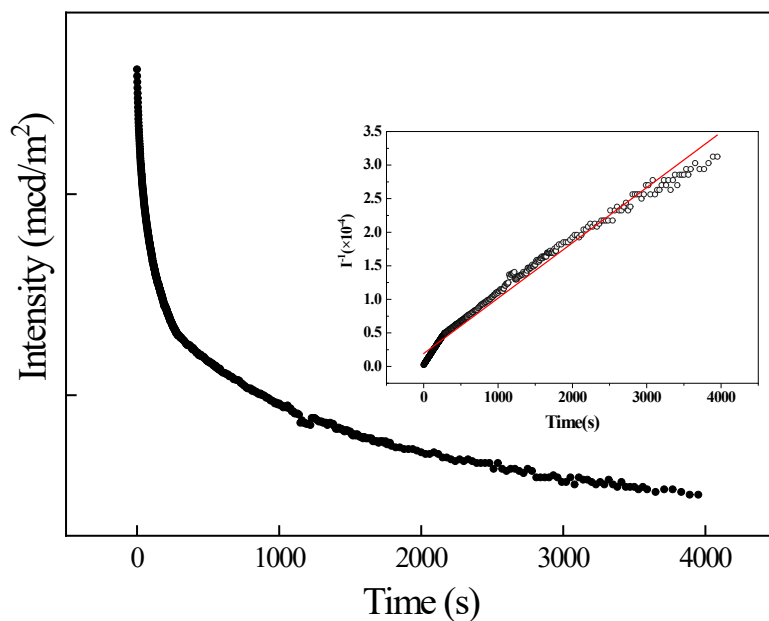


Figure S5. Visible LPL decay curve of NCSGO: 0.8%Pr³⁺, 0.8%Yb³⁺, inset is the reciprocal afterglow intensity (I^{-1}) of the visible afterglow as a function of time, the red line was the fitting result.

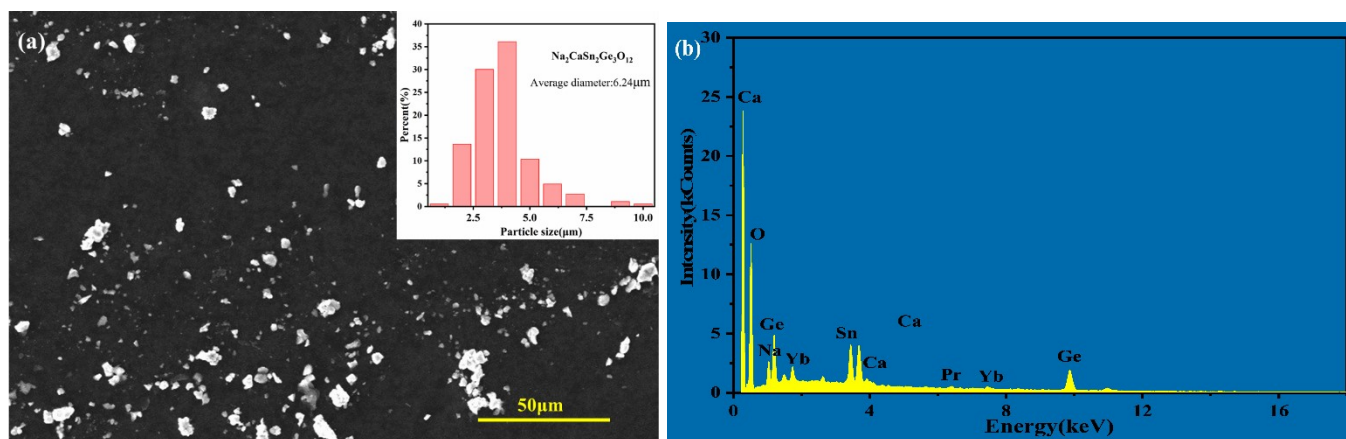


Figure S6. (a) SEM micrograph; the inset shows the particle size distribution, (b) EDX spectrum of NCSGO: 0.8%Pr³⁺, 0.8%Yb³⁺.

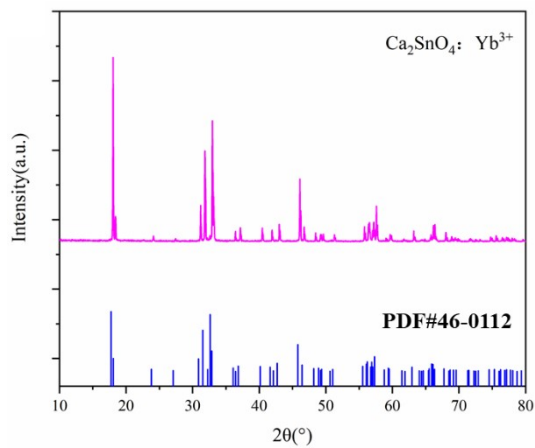


Figure S7. XRD pattern of the sample $\text{Ca}_2\text{SnO}_4: 1.0\%\text{Yb}^{3+}$

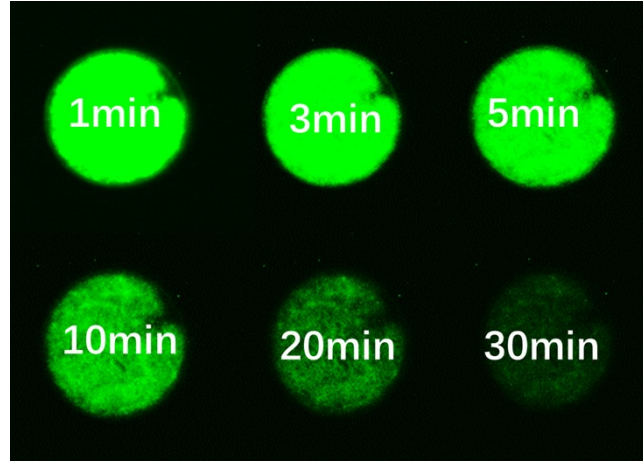


Figure S8. The near-infrared photosensitive images of NCSGO: Pr^{3+} , Yb^{3+} at different time after 10min 254nm UV lamp excitation.

Table S1. Distance of Pr^{3+} and Yb^{3+} after refinement by Rietveld.

Atom1	Summetry1	Atom2	Summetry2	Distance(Å)
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	z, x, y	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	y, z, x	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	0.5-z, -x, 0.5+y	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	0.25-z, -0.25+y, 0.25+x	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	0.25-y, -0.25+x, 0.25+z	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	-y, 0.5-z, x	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	z, -x, 0.5-y	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	0.25+y, 0.25-x, -0.25+z	3.7978
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	-z, -x, -y	5.8012
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	-0.25+z, 0.25-y, 0.75-x	5.8012
Na Ca Yb Pr	x, y, z	Na Ca Yb Pr	-x, -y, -z	6.9338

Table S2. TL spectra corresponding peak of NCSGO: $0.8\%\text{Pr}^{3+}$ and NCSGO: $0.8\%\text{Pr}^{3+}$, $0.8\%\text{Yb}^{3+}$.

Peak(Pr^{3+})	$T_m(\text{K})$	E(eV)	n_0
1	341	0.682	407892.62
2	367	0.734	735667.58

Peak($\text{Pr}^{3+}\text{-Yb}^{3+}$)	$T_m(\text{K})$	E(eV)	n_0
1	348	0.696	1661483.65
2	429	0.858	1746012.61
3	483	0.966	358615.55