Reversible photoluminescence switching in photochromic material $Sr_6Ca_4(PO_4)_6F_2:Eu^{2+}$ and the modified performance by trap engineering *via* Ln^{3+} (Ln = La, Y, Gd, Lu) co-doping for erasable optical data storage

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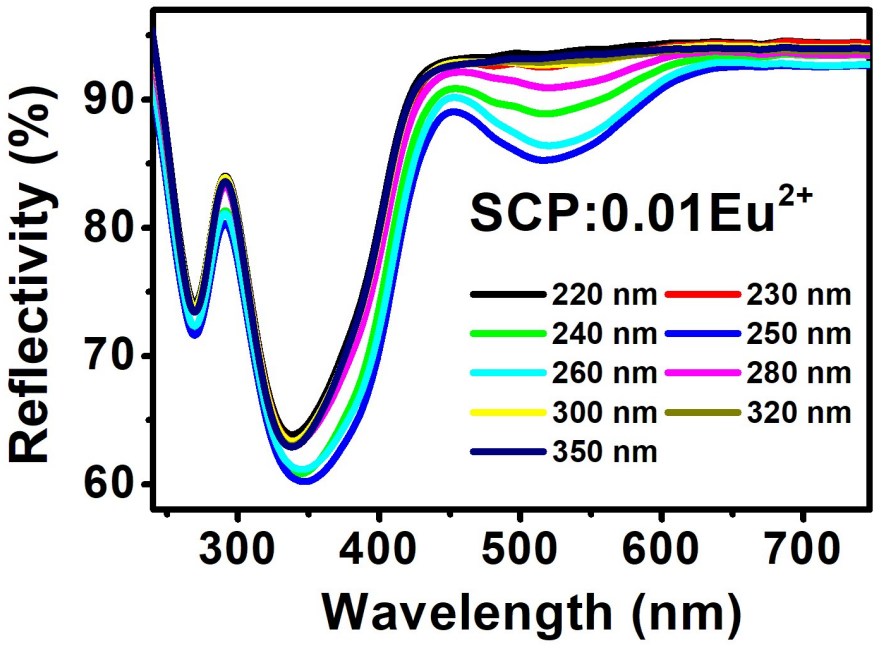

Fig. S1 Reflection spectra of sample SCP:0.01Eu^{2+} after different wavelength light irradiation.

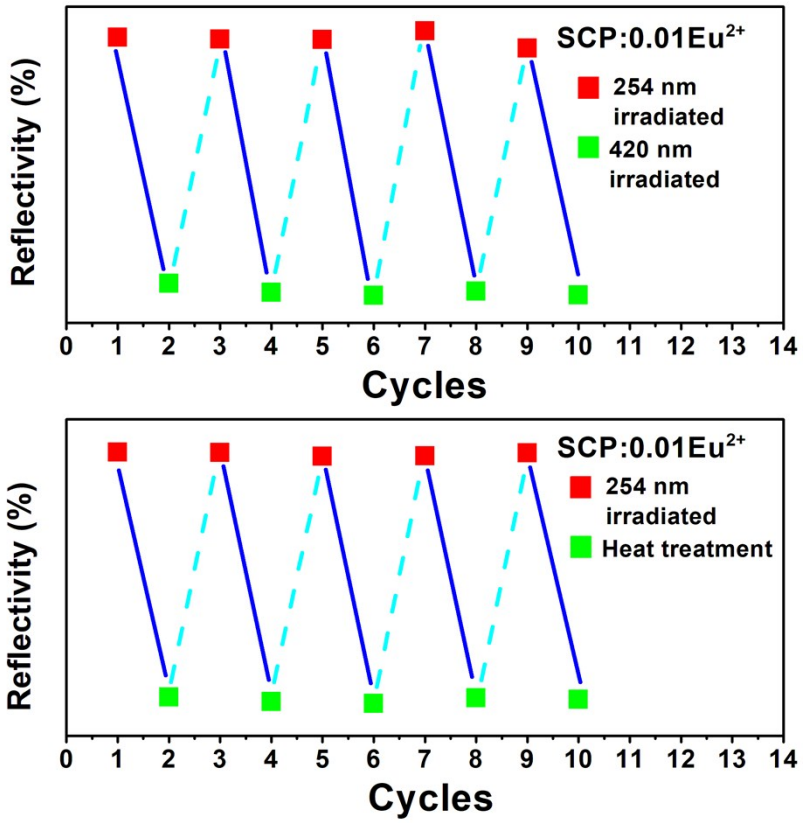

Fig. S2 (a) Several cycles of sample SCP:0.01Eu^{2+} after alternately UV light and visible light irradiation, (b) several cycles of sample SCP:0.01Eu^{2+} after alternately UV light and heat treatment.

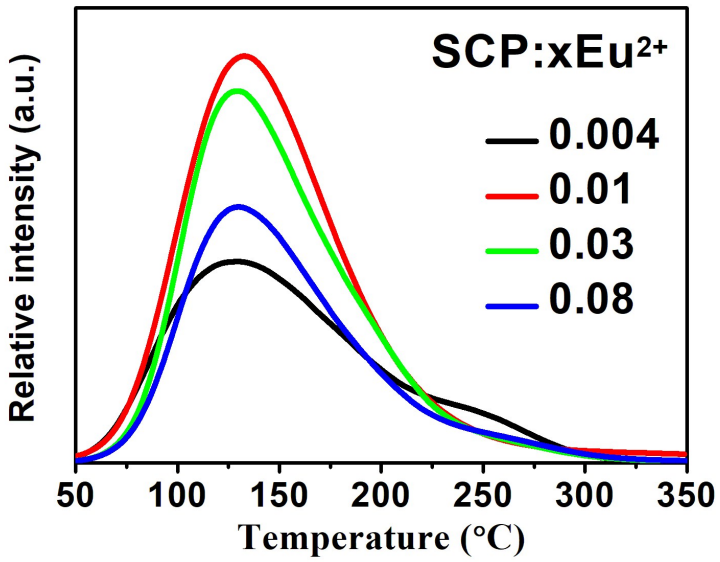

Fig. S3 TL curves of sample SCP:xEu^{2+} (x=0.004, 0.01, 0.03 and 0.08).

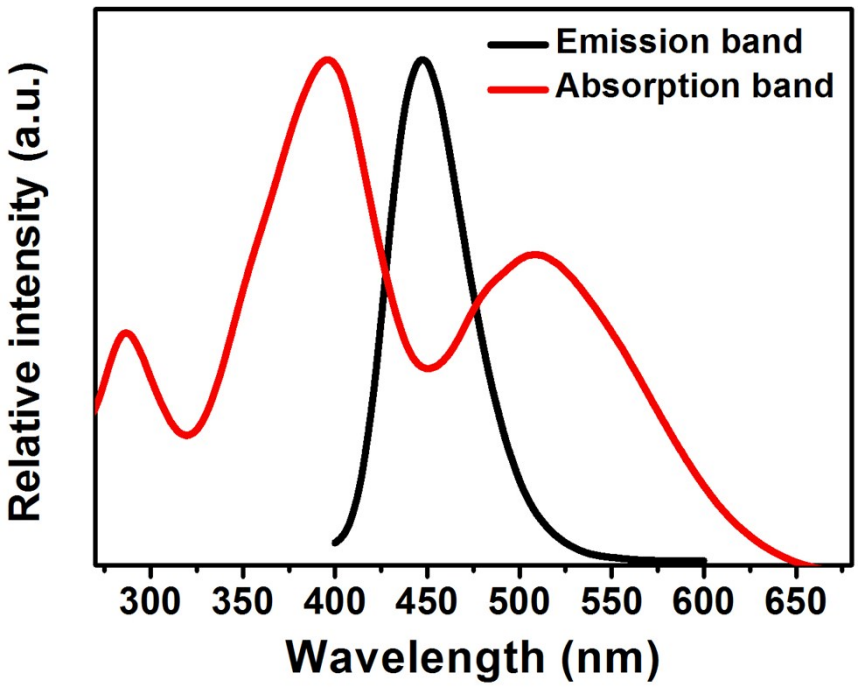

Fig. S4 The overlap of emission band and absorption band of sample SCP:0.01Eu^{2+}.

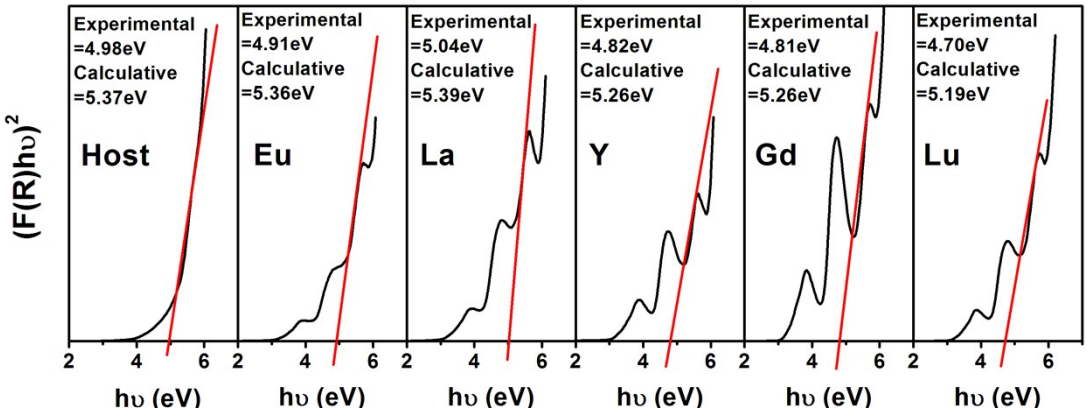

Fig. S5 The function of *(F(R)hv)*^{2} versus on *hv* for sample SCP with single Eu^{2+} doped and co-doping Ln^{3+} (Ln = La, Y, Gd and Lu) ions.

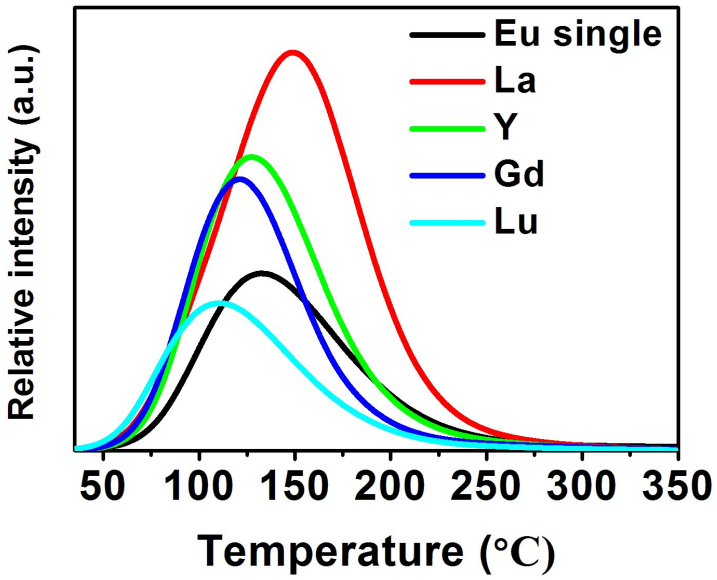

Fig. S6 TL curves of sample SCP:0.01Eu^{2+} and SCP:0.01Eu^{2+}, 0.01Ln^{3+} (Ln=La,Y, Gd, Ln).

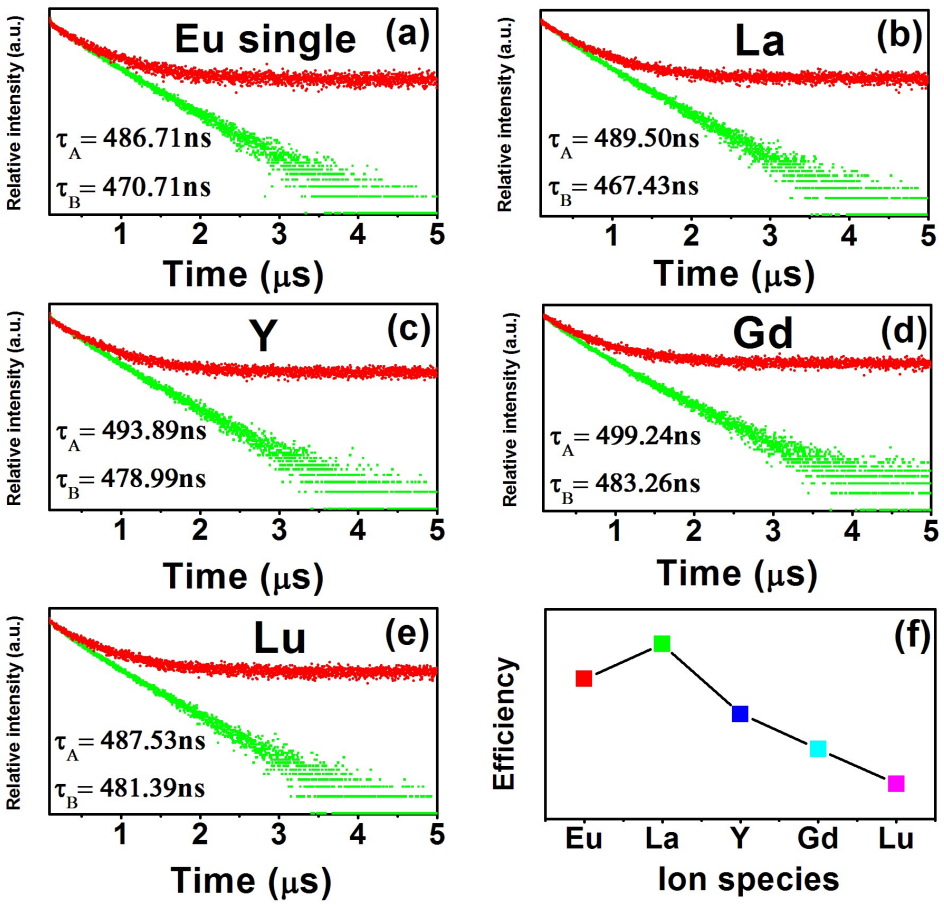

Fig. S7 Fluorescence lifetime before and after UV light irradiation of sample (a) SCP:0.01Eu^{2+}, (b)SCP:0.01Eu^{2+}, 0.01La^{3+}, (c)SCP:0.01Eu^{2+}, 0.01Y^{3+}, (d)SCP:0.01Eu^{2+}, 0.01Gd^{3+}, (e)SCP:0.01Eu^{2+}, 0.01Lu^{3+}, (f) the energy transfer efficiency of sample SCP:0.01Eu^{2+} and SCP:0.01Eu^{2+}, 0.01Ln^{3+} (Ln=La,Y, Gd, Ln).

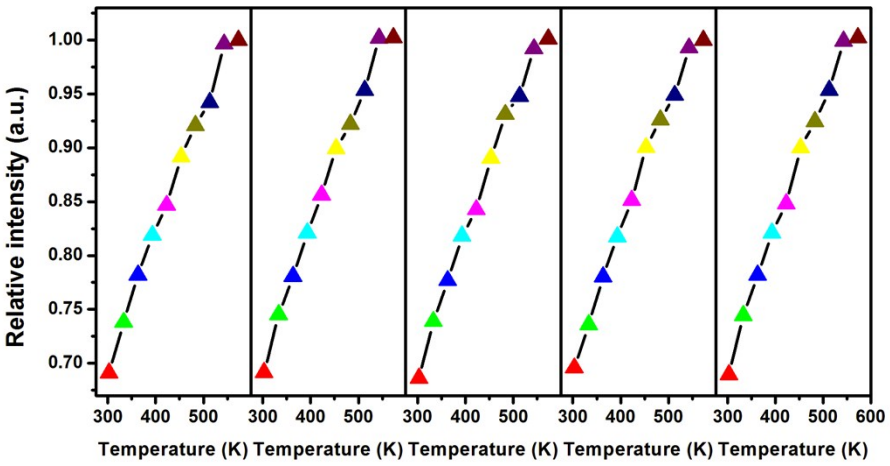

Fig. S8 Relative PL intensity of colored sample with different temperature treatment undergo several cycles.

Table S1. Refined structure parameters of $Sr_6Ca_4(PO_4)_6F_2$:0.01Eu^{2+} derived from the Rietveld refinement of X-ray diffraction data.

Atoms	Wyckoff position	x	y	z	Frac.
Ca1	2b	0.3333	0.6667	0.0000	1.0000
Sr1	2b	0.3333	0.6667	0.5000	1.0000
Sr2	6c	0.2390	0.2550	0.2500	0.6667
Ca2	6c	0.2390	0.2550	0.2500	0.3333
P1	6c	0.3710	0.3990	0.7400	1.0000
F1	2a	0.0000	0.0000	0.0600	1.0000
O1	6c	0.4920	0.3420	0.7300	1.0000
O2	6c	0.4720	0.5900	0.7800	1.0000
O3	6c	0.2590	0.3290	0.9100	1.0000
O4	6c	0.2600	0.3850	0.5700	1.0000

Crystal system: hexagonal

Space group: P-63

Cell parameters: a=9.575818 Å, b=9.575818 Å, c=7.114803 Å

α=90°, β=90°and γ=120°

Cell volume: 564.996 $Å^3$

Z=2

R_{wp} = 14.14 %, R_p = 10.13 % and χ^2 = 5.58