Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Charge carrier trapping processes in lanthanide doped La-, Gd-, Y-, and $LuPO_4$

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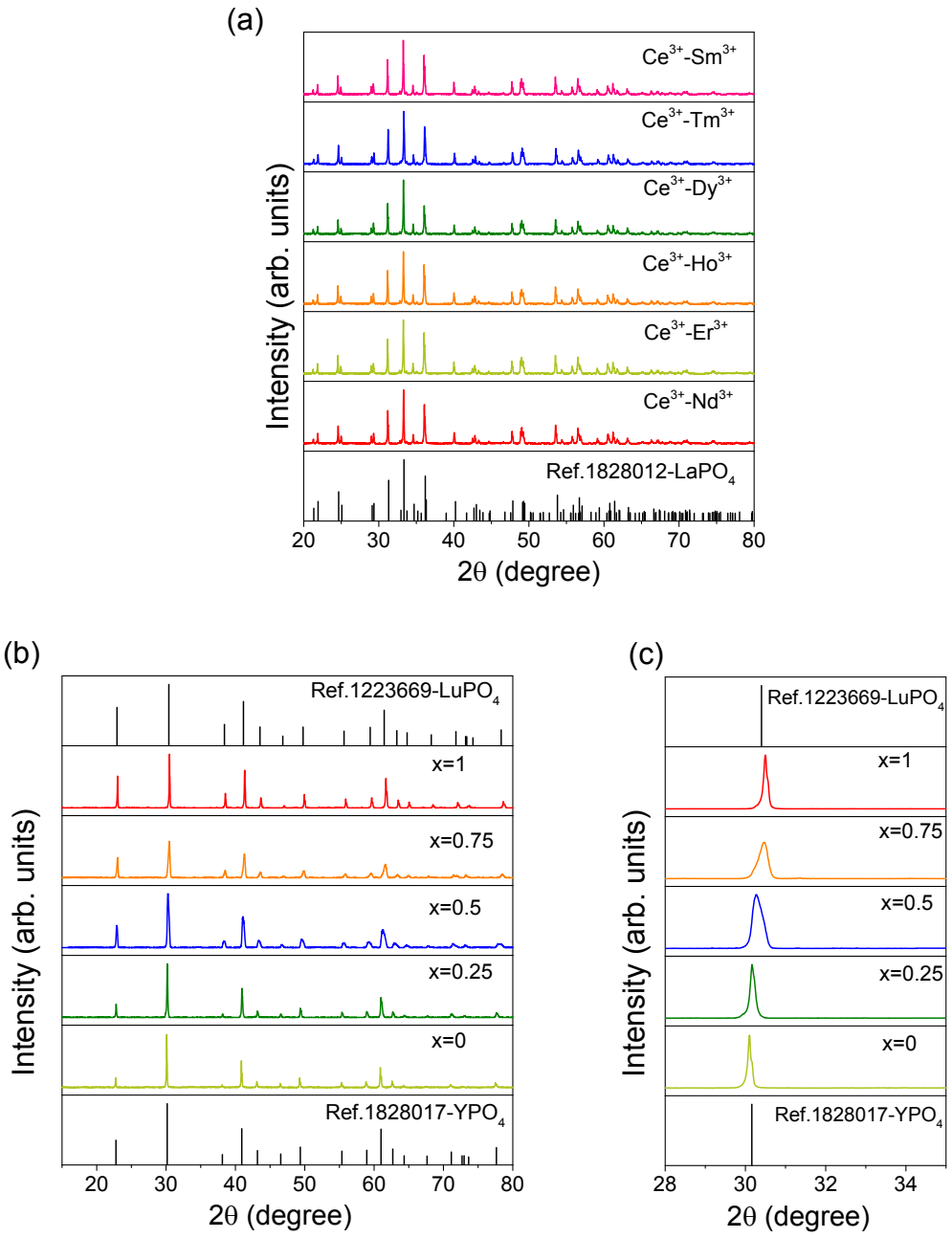

Fig. S1. XRD patterns of (a) $LaPO_4$:0.005Ce^{3+},0.005Ln^{3+}. (b) XRD patterns and (c) detailed patterns in the range from 28 to 35° for $Y_{1-x}Lu_xPO_4$:0.005Eu^{3+},0.005Tb^{3+} solid solutions.

Fig. S1a shows the XRD patterns of $LaPO_4$:0.005Ce^{3+},0.005Ln^{3+}. All samples are of single phase and match well with the $LaPO_4$ reference (No. 1828012).

Fig. S1b shows the XRD patterns of $Y_{1-x}Lu_xPO_4$:0.005Eu^{3+},0.005Tb^{3+}. The XRD peaks show a slight shift towards larger 2θ angles compared to YPO_4 because lutetium ions enter into the larger yttrium sites and decrease the cell volume. With increasing x, solid solution appears since both YPO_4 and $LuPO_4$ have the same crystal structure (space group: $I4_1/amd$ O_2).

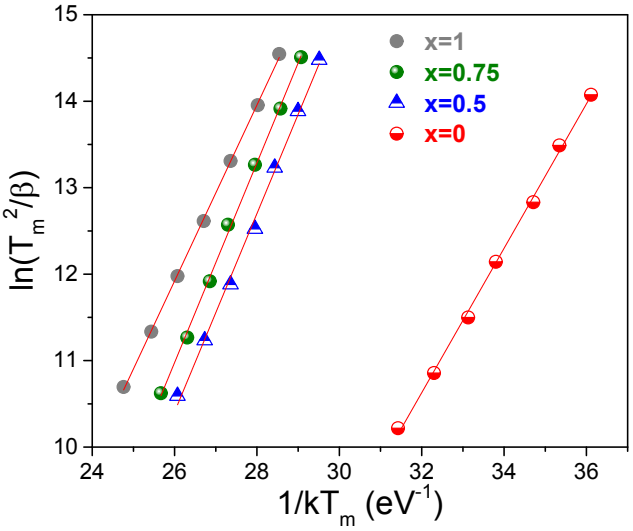

Fig. S2. Variable heating rate plots of $Gd_{1-x}La_xPO_4$:0.005Ce^{3+},0.005Ho^{3+} (x=0, 0.5, 0.75, and 1) solid solutions. The used heating rates were 0.08, 0.15, 0.30, 0.63, 1.25, 2.5, and 5 K/s.

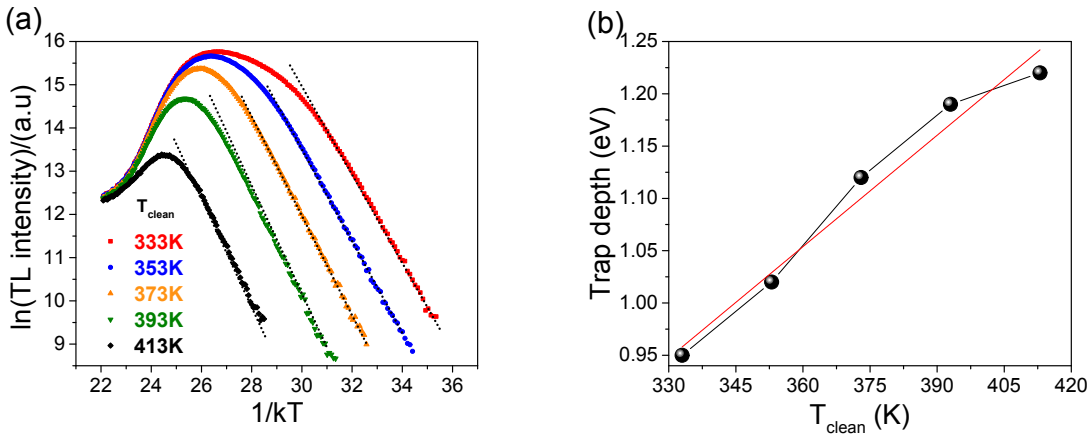

Fig. S3. (a) Initial rise analysis on all TL glow curves as a function of T_{clean} for x=0.25. (b) calculated trap depth. The red solid line is a linear fit through the data points.

The initial rise method was used to determine the trap depth at T_{clean}. The rising part of TL intensity (I(T)) can be approximated using[1-6]

$$I(T) = C \times \exp\left(\frac{-E}{kT}\right) \qquad (1)$$

where C is a constant. Fig. S3a shows the initial rise plots of TL glow curves for x=0.25 after different peak temperature T_{clean}. Straight line sections appear in the low temperature part. With increasing the T_{clean}, the trap depth derived from the slope increases from 0.95 to 1.2 eV as shown in Fig. S3b.

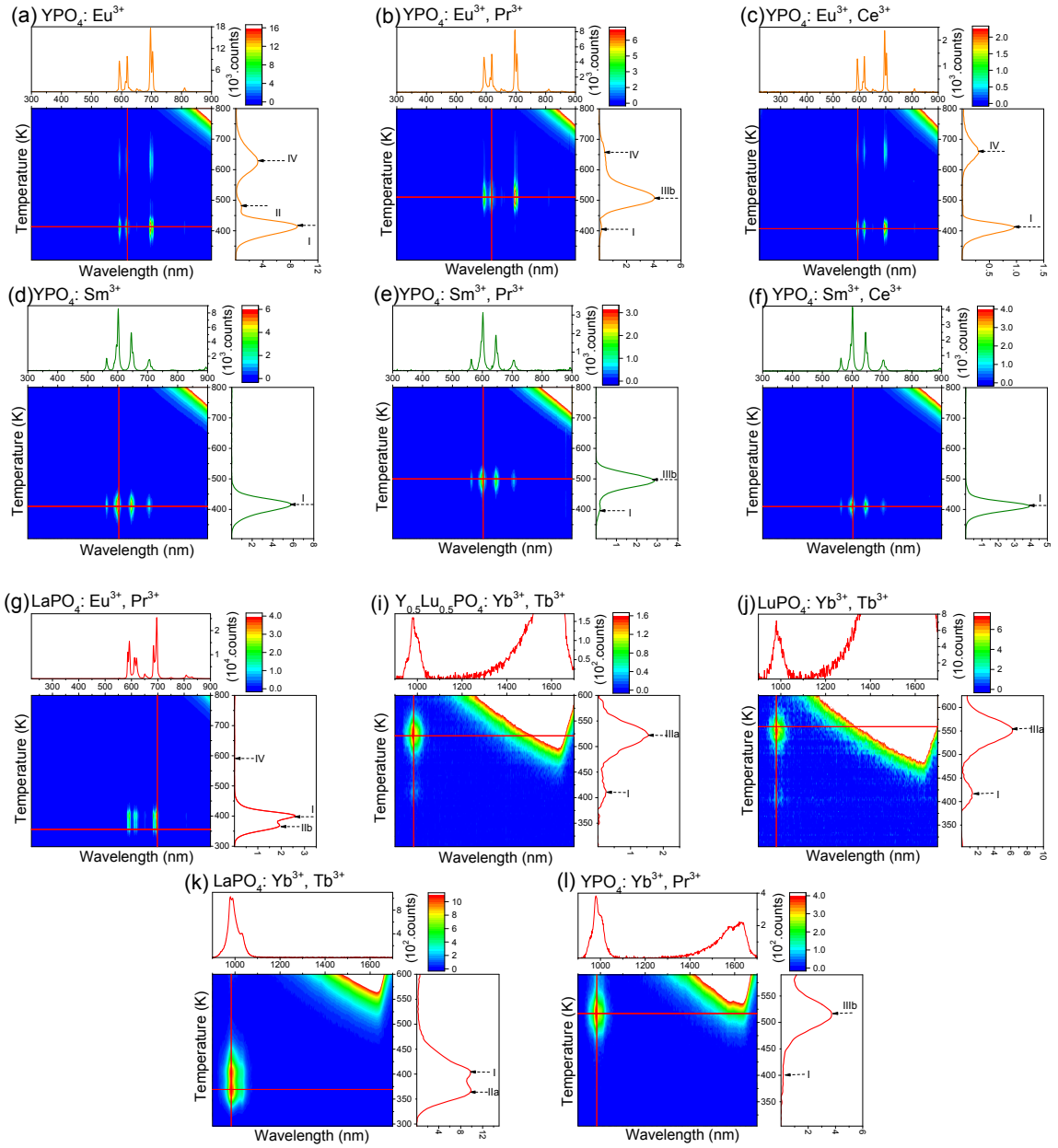

Fig. S4. Thermoluminescence emission (TLEM) plots of $REPO_4$:0.005Ln^{3+} (RE=La, Y, and Lu) samples recorded at the heating rate of 1 K/s.

Compared to YPO_4:0.005Yb^{3+},0.005Tb^{3+} (Fig. 8c), it is also noticed in Fig. S4i-j that the glow peak IIIa from the Tb^{3+} hole tapping center shifts about 45 K (0.33 eV) towards higher temperature in the $Y_{1-x}Lu_xPO_4$:0.005Yb^{3+},0.005Tb^{3+} solid solutions with increasing x leading to the decreasing of the VRBE at the valence band top and the increased hole trap depth of Tb^{3+}. This observation is similar to that of glow peaks IIIa and IIIb shifting in $Y_{1-x}Lu_xPO_4$: 0.005Eu^{3+},0.005Tb^{3+} (Fig. 10) and $Y_{1-x}Lu_xPO_4$:0.005Eu^{3+},0.005Pr^{3+} solid solutions (Fig. S7).

Note that the glow at around 1200-1700 nm appears in Fig. Si-l, which is due to blackbody radiation.

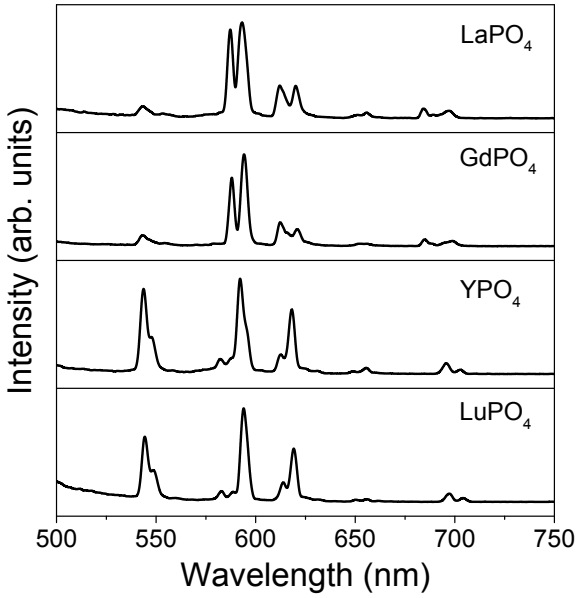

Fig. S5. Photoluminescence spectra of $REPO_4$:0.005Eu^{3+},0.005Tb^{3+} (RE=La, Gd, Y, and Lu) at 10 K. Samples were excited at the Eu^{3+}-CT peak maxima.

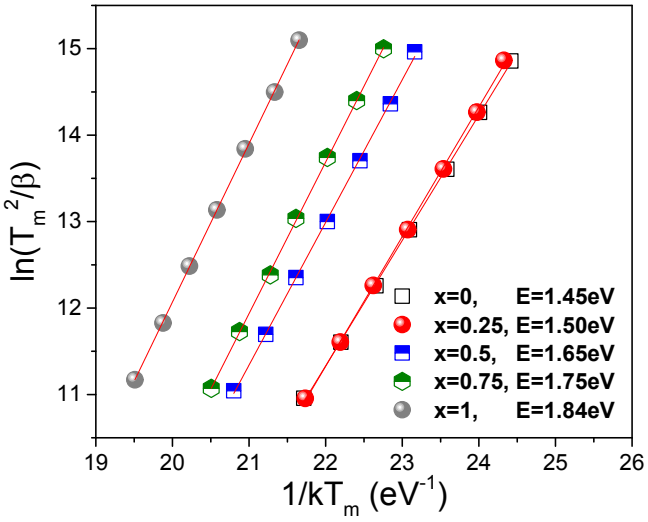

Fig. S6. Variable heating rate plots of $Y_{1-x}Lu_xPO_4$:0.005Eu^{3+},0.005Tb^{3+} solid solutions. The used heating rates were 0.08, 0.15, 0.30, 0.63, 1.25, 2.5, and 5 K/s.

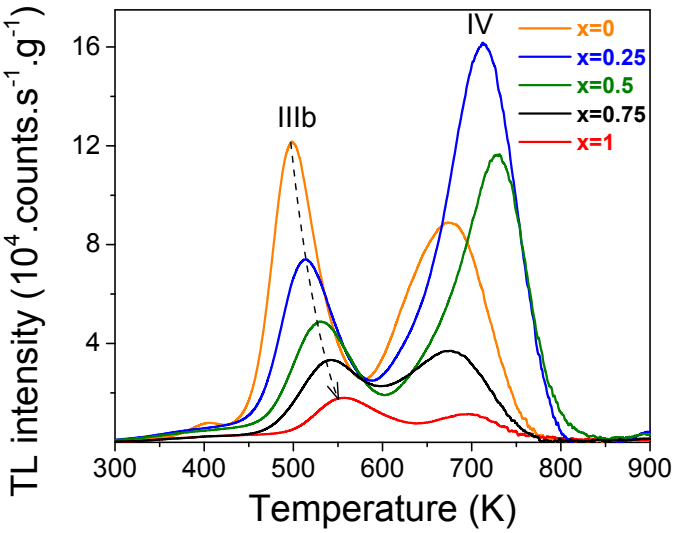

Fig. S7. TL glow curves for $Y_{1-x}Lu_xPO_4$:0.005Eu^{3+},0.005Pr^{3+} solid solutions monitoring the emission from Eu^{3+} at the heating rate of 1 K/s.

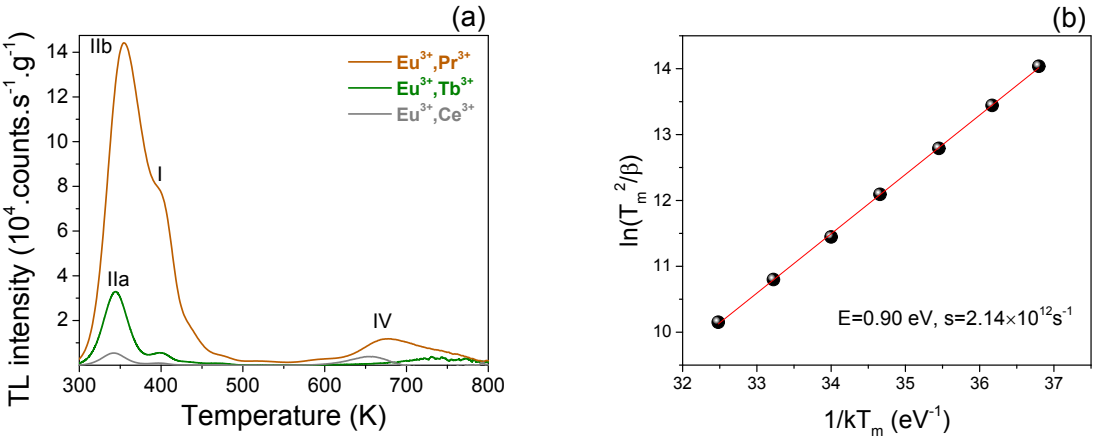

Fig. S8. (a) TL glow curves for $LaPO_4$:0.005Eu^{3+},0.005Ln^{3+} (Ln=Tb, Pr, and Ce) monitoring the Eu^{3+} emission at 300-800 K at the heating rate of 1 K/s. (b) variable heating rate plot of $LaPO_4$:0.005Eu^{3+},0.005Tb^{3+} sample. The used heating rates are 0.08, 0.15, 0.30, 0.63, 1.25, 2.5, and 5 K/s.

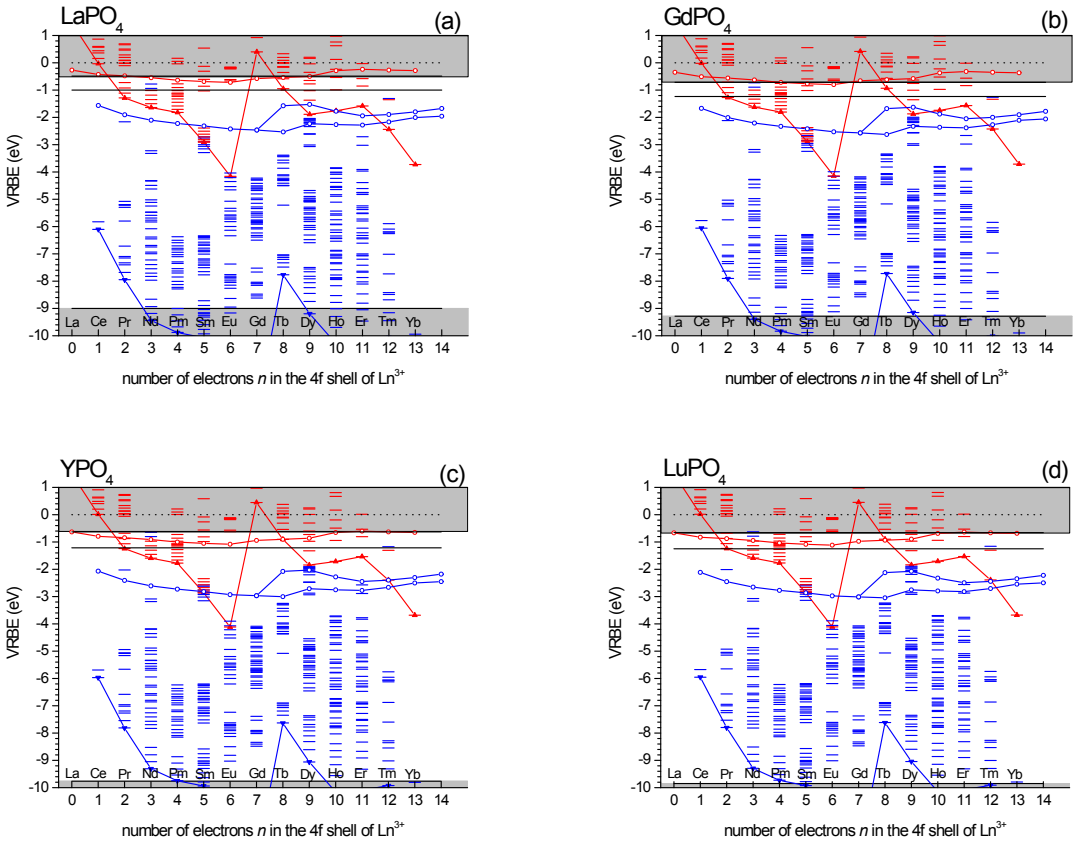

Fig. S9. Vacuum referred binding energy (VRBE) diagrams of all lanthanide levels in (a) $LaPO_4$, (b) $GdPO_4$, (c) YPO_4, and (d) $LuPO_4$.

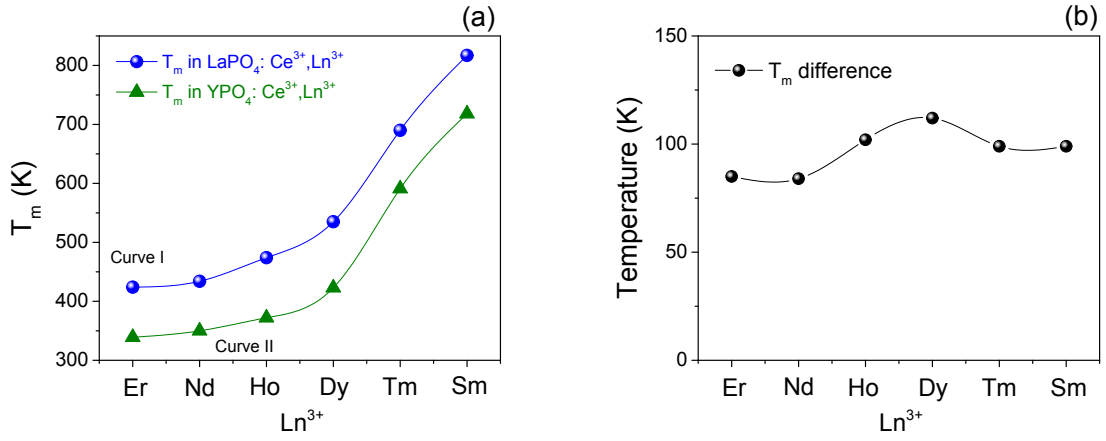

Fig. S10. (a) Peaks T_m for the TL glow curves of $REPO_4$:0.005Ce^{3+},0.005Ln^{3+} (RE=La and Y) and (b) T_m difference between curve I and curve II.

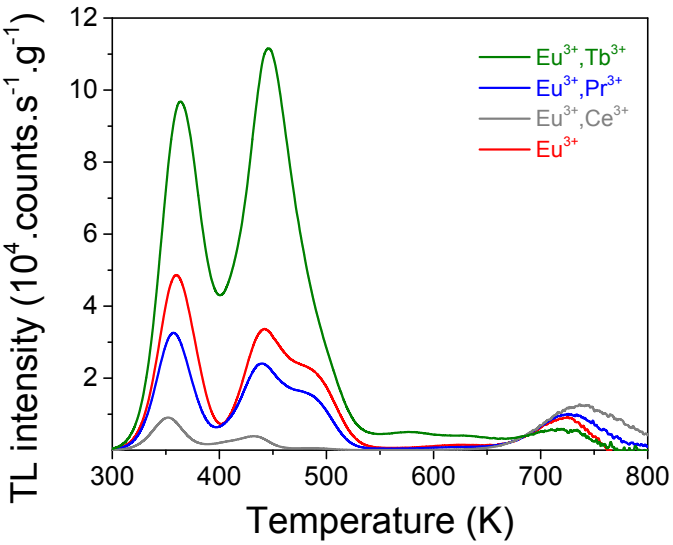

Fig. S11. TL glow curves for $GdPO_4$:0.005Eu^{3+},0.005Ln^{3+} (Ln=Tb, Pr, and Ce) samples monitoring the Eu^{3+} emission at the heating rate of 1 K/s.

Reference

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