Supporting Information

The influence of the dopant concentration on temperature dependent emission spectra in $LiLa_{1-x-y}Eu_xTb_yP_4O_{12}$ nanocrystals: toward rational designing of highly-sensitive luminescent nanothermometer

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KEYWORDS: luminescent thermometer, nanocrystals, Tb3+, Eu3+, cross-relaxation, energy transfer

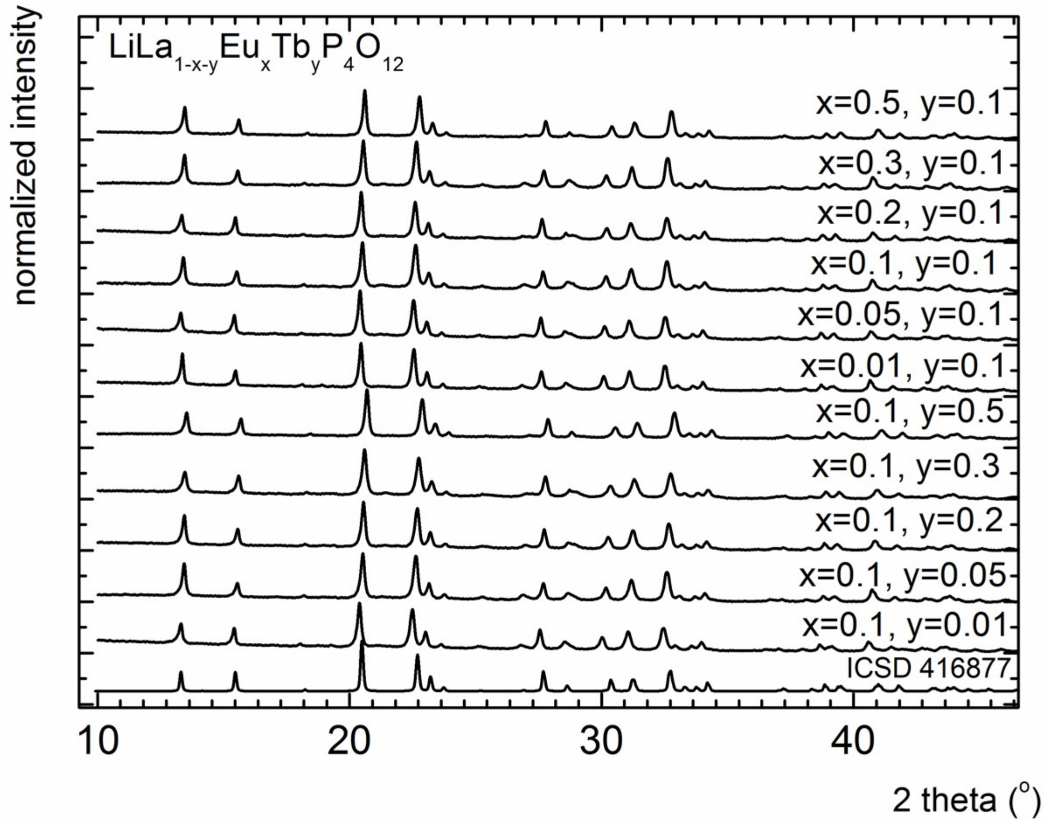

Figure S1. X-ray diffraction data for $LiLa_{1-x-y}Eu_xTb_yP_4O_{12}$ nanocrystals

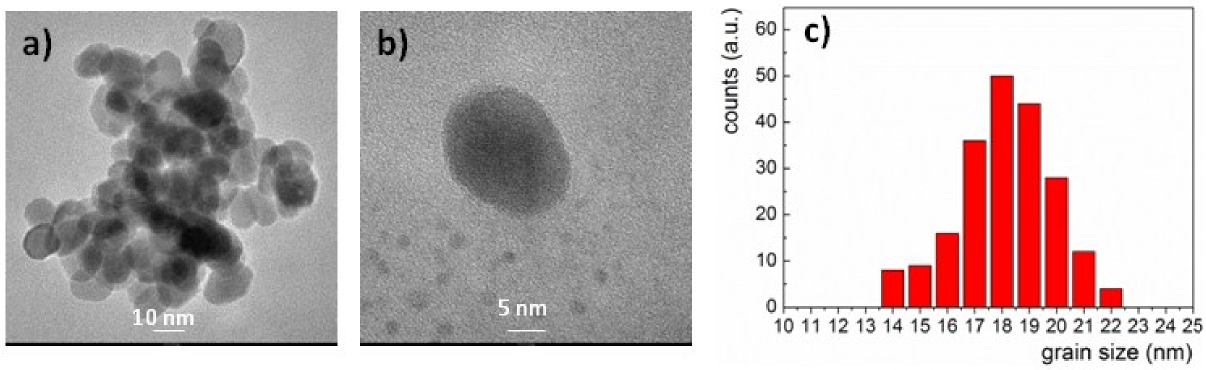

Figure S2. TEM images of $LiLa_{0.5}Eu_{0.1}Tb_{0.4}P_4O_{12}$ nanocrystals –a and b with grain size distribution –c.

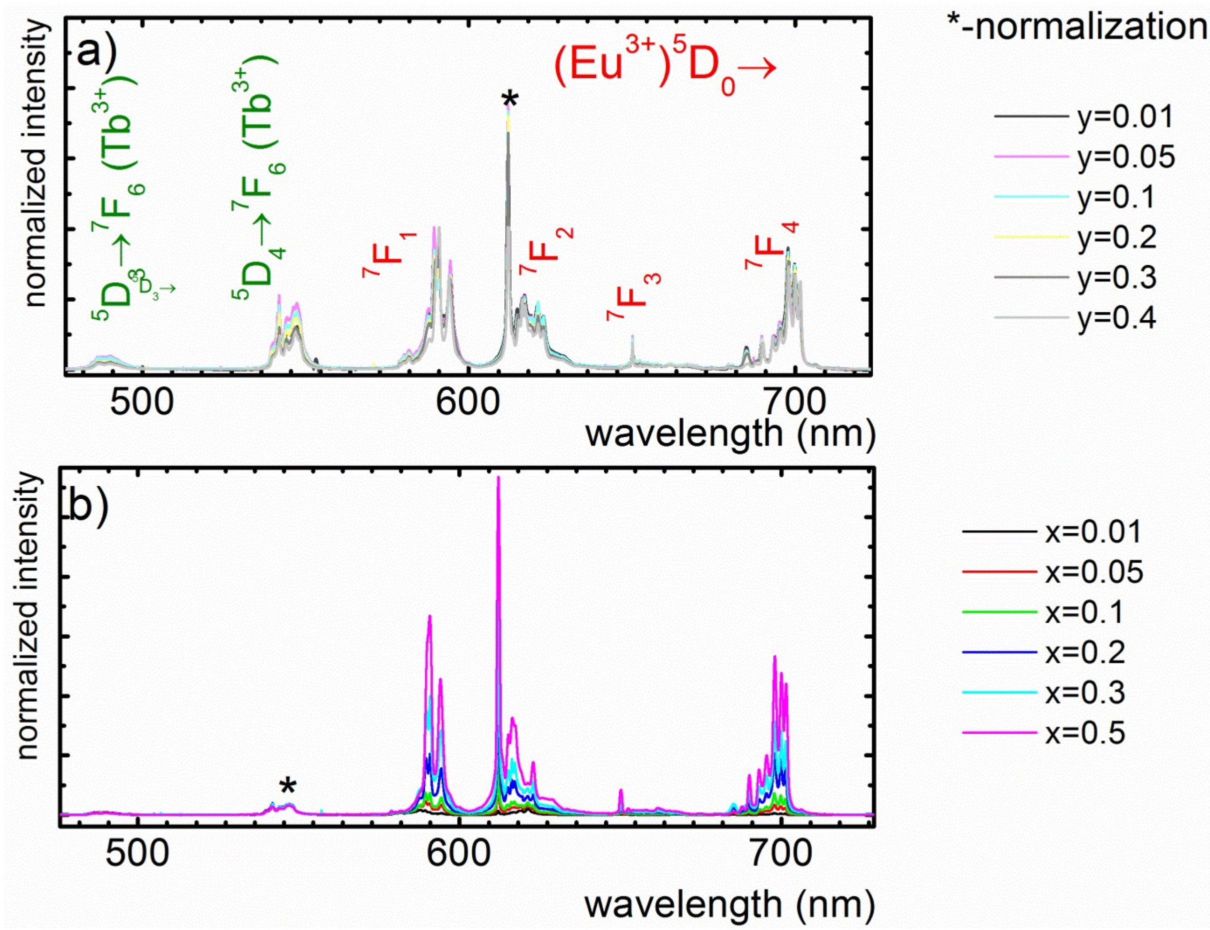

Figure S3. The comparison of emission spectra of $LiLa_{1-x-y}Eu_xTb_yP_4O_{12}$ for constant x=0.1 concentration of Eu^{3+} ions-a; and for constant x=0.1 concentration of Tb^{3+} ions-b.

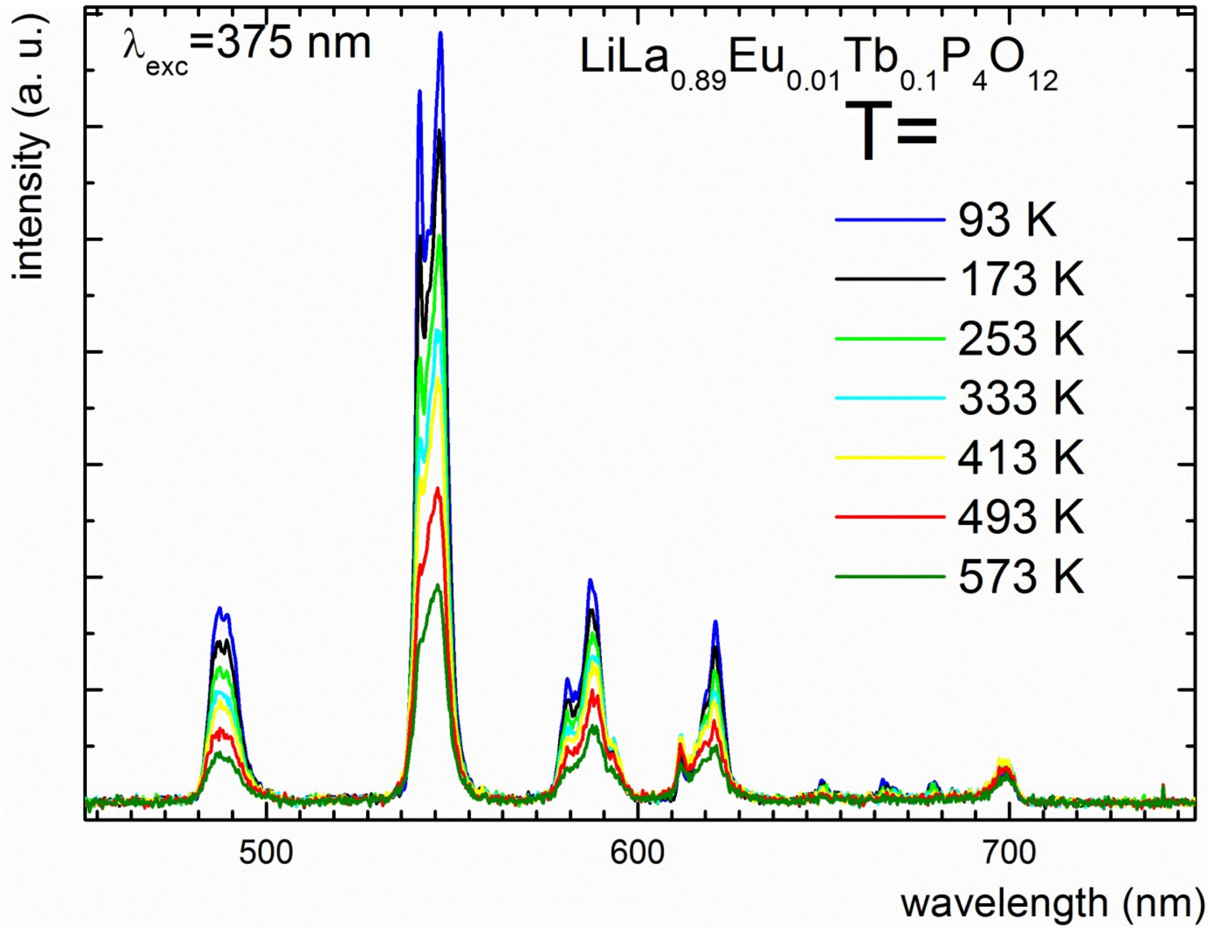

Figure S4. Emission spectra of $LiLa_{0.89}Eu_{0.01}Tb_{0.1}P_4O_{12}$ nanocrystals measured at different temperatures.

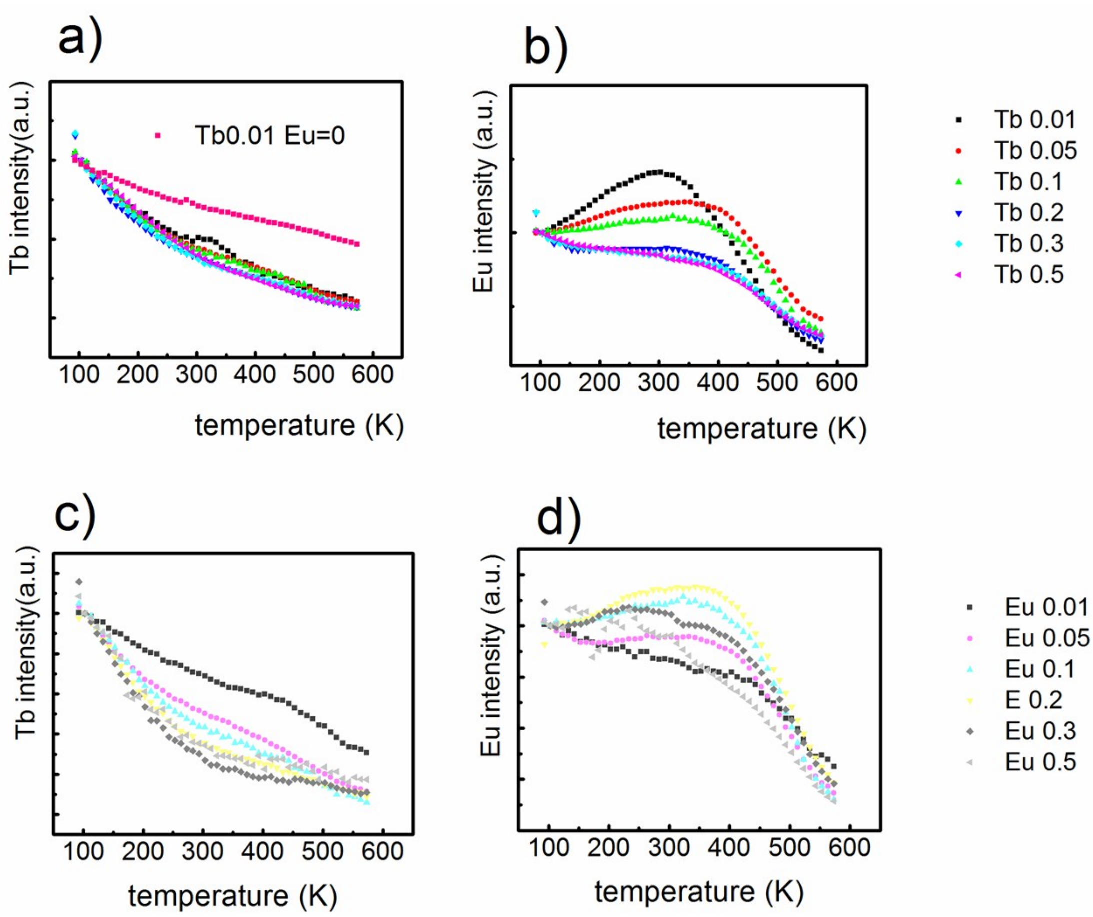

Figure S5. Temperature evolution of Tb^{3+} (a) and Eu^{3+} (b) emission intensities in $LiLa_{1-x-y}Eu_xTb_yP_4O_{12}$ nanocrystals for samples doped with constant x=0.1 Eu^{3+} ions concentration and different Tb^{3+} concentration; temperature evolution of Tb^{3+} (c) and Eu^{3+} (d) emission intensities respectively for samples doped with constant x=0.1 Tb^{3+} ions concentration and different Eu^{3+} concentration.

Energy transfer which can take place between Eu^{3+} and Tb^{3+} ions can be described by following rate equations:

$$\frac{dn_0}{dt} = -\Phi n_0 + n_3 W_{30} + n_4 W_{40} + n_8 n_1 W^{10} - n_4 n_0 W^{CR4} \quad \text{(S1)}$$

$$\frac{dn_1}{dt} = n_3 W_{31} + n_4 W_{41} - n_8 n_1 W^{10} - n_1 W^{1NR} \quad \text{(S2)}$$

$$\frac{dn_2}{dt} = n_3 W_{32} + n_4 W_{42} + n_4 n_0 W^{CR4} - n_2 W^{2NR} \quad \text{(S3)}$$

$$\frac{dn_3}{dt} = -n_3 W_3 - W^{ET38} n_3 + n_4 n_0 W^{CR4} + n_4 n_5 W^{CR5} + W^{BET}{}_{83} n_8 - W^{3NR} n_3 + W^{4NR} n_4 \quad \text{(S4)}$$

$$\frac{dn_4}{dt} = \Phi n_0 - n_4 W_4 - n_4 n_0 W^{CR4} - n_4 n_5 W^5 - n_4 W^{4NR} \quad \text{(S5)}$$

$$\frac{dn_5}{dt} = n_7 W_{71} - n_5 n_4 W^5 + n_6 n_8 W^{11} \quad \text{(S6)}$$

$$\frac{dn_6}{dt} = -n_6 n_8 W^{11} + n_7 W^{7NR} + W_{86} n_8 - W^{NR6} n_6 \quad \text{(S7)}$$

$$\frac{dn_7}{dt} = -W^{7NR} n_7 + n_5 n_4 W^5 + W^{87} n_8 + W^{7NR} n_7 \quad \text{(S8)}$$

$$\frac{dn_8}{dt} = -n_8 W_8 - n_8 n_6 W^{11} - n_8 n_1 W^{10} + W^{9NR} n_9 - n_8 W^{NR8} \quad \text{(S9)}$$

$$\frac{dn_9}{dt} = -W^{NR9} n_9 + W^{10} n_9 n_1 - n_9 W^{BET}{}_{93} + n3 W^{ET}{}_{93} + W^{NR10} n_{10} \quad \text{(S10)}$$

$$\sum_i n_i = N \quad \text{(S11)}$$

$$\frac{n_i}{N} = N_i \quad \text{(S12)}$$

where W^{NRi} represent the nonradiative decay rate of the i^{th}-state, W_{ij} represents the probability of radiative transition between i and j states, W_{ij}^{ET} represents probability of energy transfer between i and j state and BET is back ($Eu^{3+} \rightarrow Tb^{3+}$) energy transfer probability. W^{CR10} represents probability of cross relaxation process represented as process 10 in Fig. 5 and n_i is the population of i^{th} state.