Supplementary Materials

Microstructure and photoluminescence of $ZrTiO_4:Eu^{3+}$ phosphors: host-sensitized energy transfer and optical thermometry

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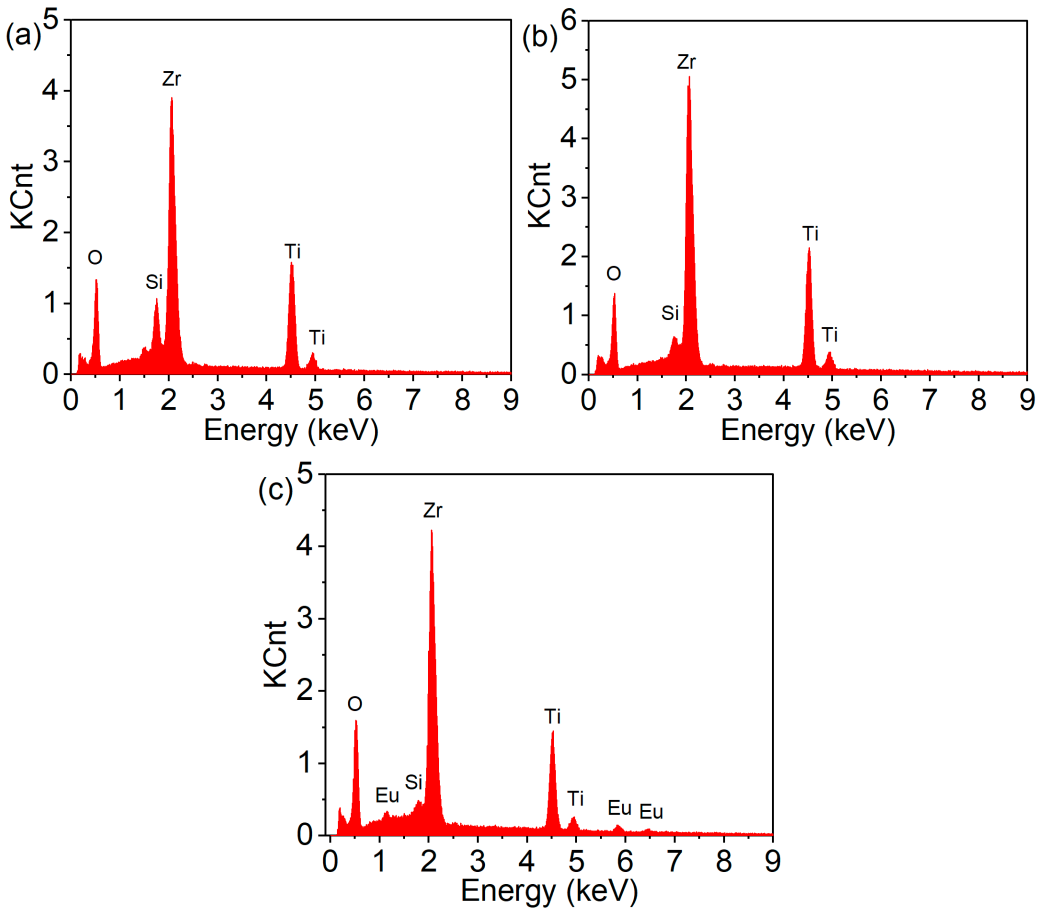

Element analysis

Samples	Element (At%)			
	O	Zr	Ti	Eu
$ZrTiO_4$	65.66	16.68	17.66	-
$Zr_{0.99}Eu_{0.01}TiO_4$	60.20	19.04	20.57	-
$Zr_{0.95}Eu_{0.05}TiO_4$	66.23	15.87	16.86	1.04

Figure S1. EDS spectra of $Zr_{1-x}Eu_xTiO_4$(x = 0(a), 0.01 (b), 0.05(c)) and the relative content of different elements in the samples derived from EDS analysis. The signals of Eu^{3+} was not detected at lower doping concentration ($x \leq 0.01$); The Si signals detected are from the silicon substrate used to support the powdered samples.

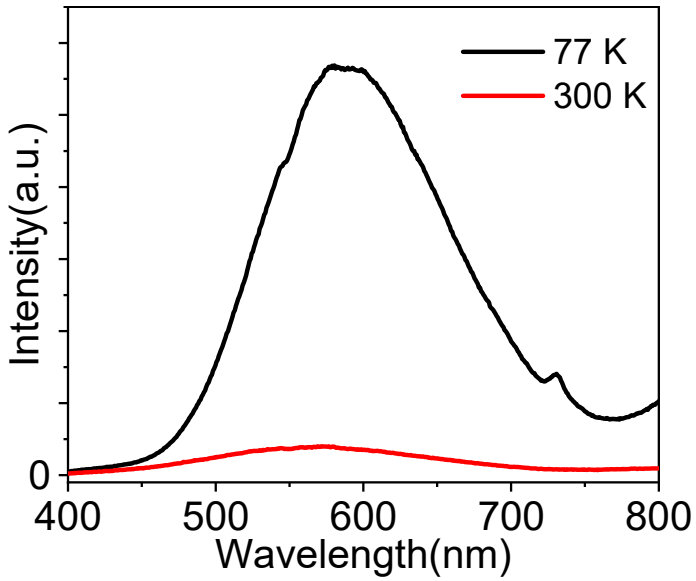

Figure S2. PL spectra of the $ZrTiO_4$ recorded at 77K and room temperature (λ_{ex}=340 nm). The luminescence peaking at ~725 nm and the band above 800 nm are probably from crystal- field transitions of traces of transition metal impurities (e.g., Cr^{3+}, Mn^{4+}), which were commonly contained in the commercially available TiO_2 starting materials.

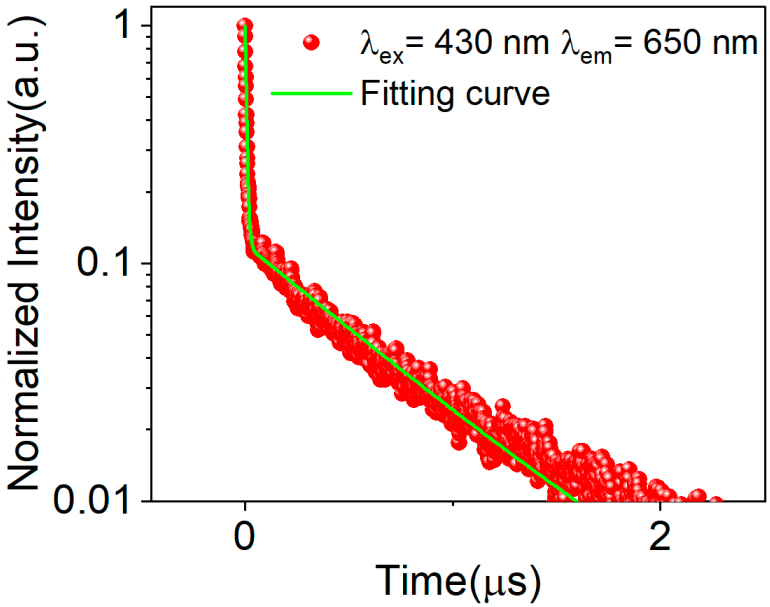

Figure S3. Fluorescence decay trace of 650 nm emission in $ZrTiO_4$ upon excitation at 430 nm at 77K.

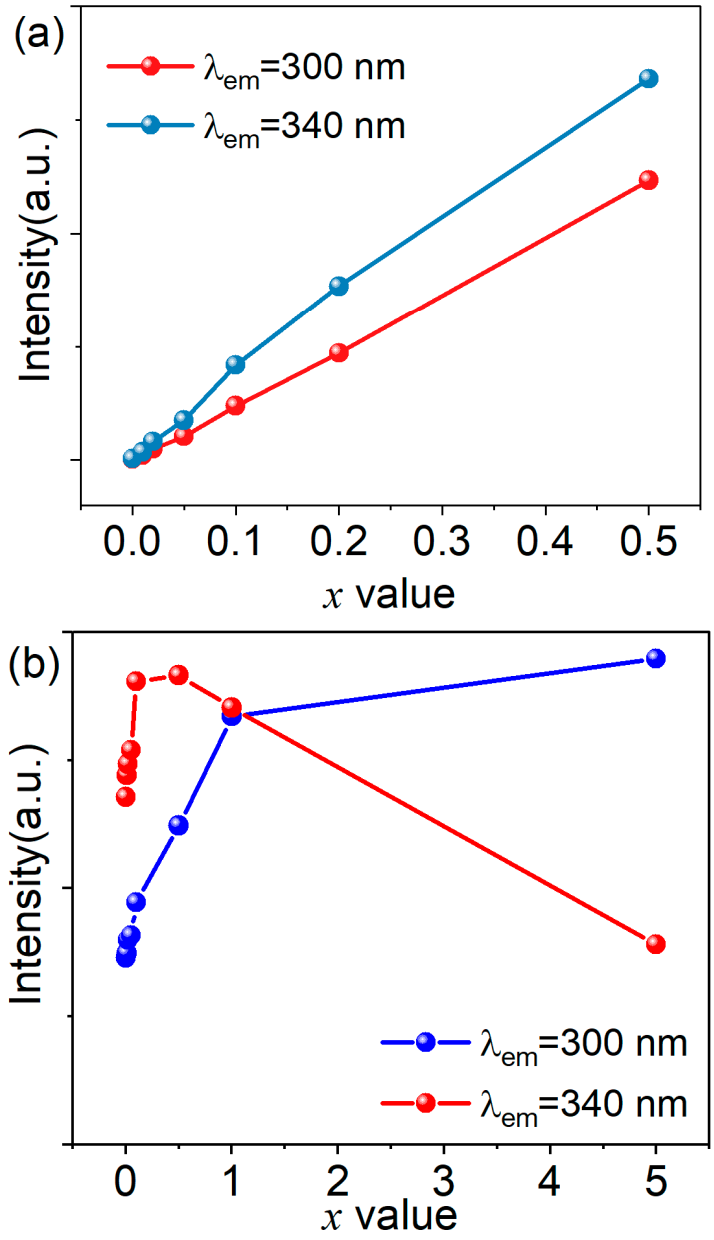

Figure S4. The luminescence intensity of 612 (a) 520 nm (b) emissions in $Zr_{1-x}Eu_xTiO_4$(x = 0.0001, 0.0005, 0.002, 0.005, 0.01, 0.05) phosphors upon host excitation at 300 and 340 nm.

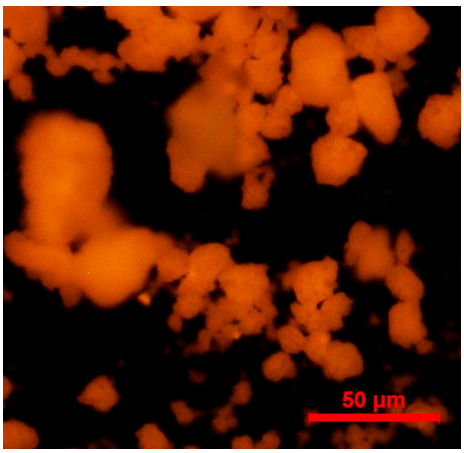

Figure S5. Fluorescence microscopy image (200×) of $Zr_{0.99}Eu_{0.01}TiO_4$ under excitation of 340-370 nm.

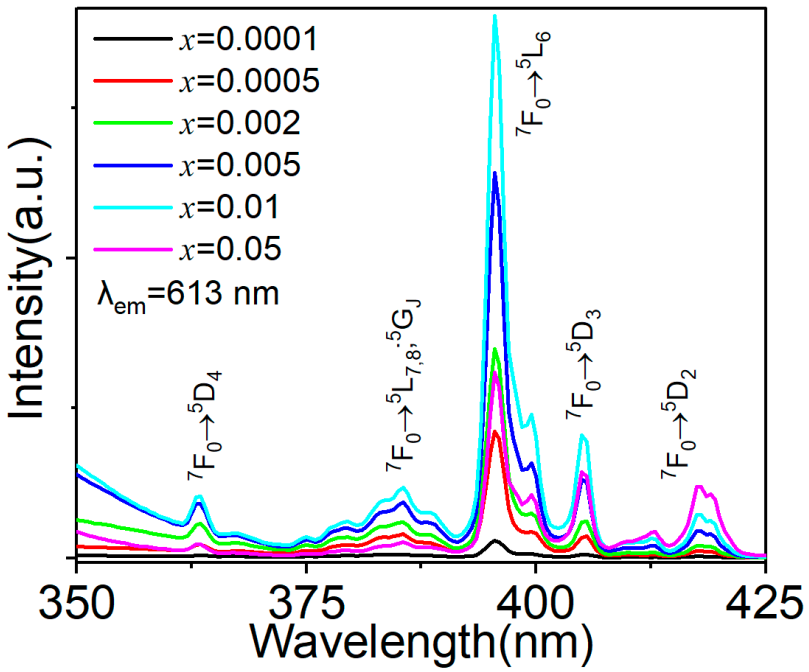

Figure S6. Excitation spectra of $Zr_{1-x}Eu_xTiO_4$(x= 0, 0.0001, 0.0005, 0.002, 0.005, 0.01, 0.05) phosphors of Eu^{3+} emissions (λ_{em}=613 nm).

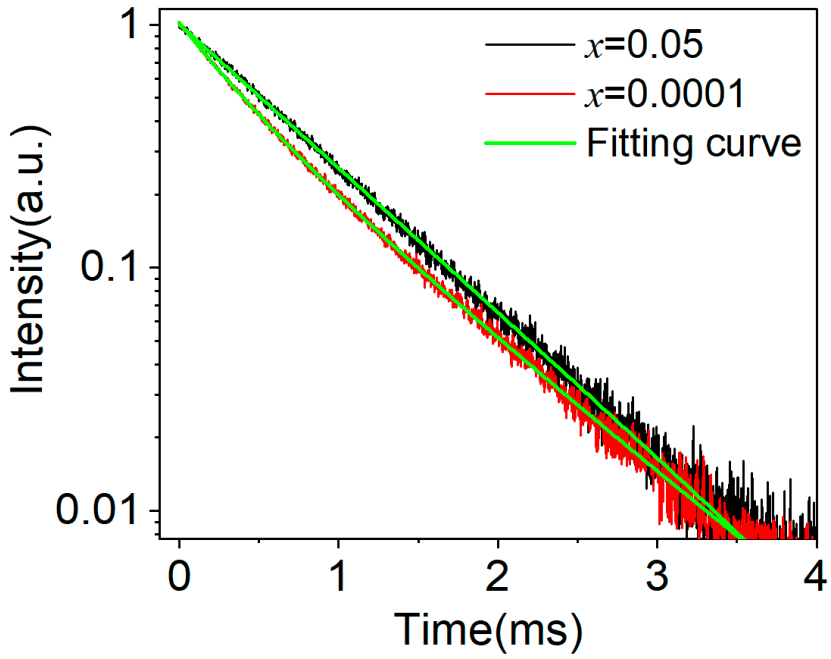

Figure S7. Fluorescence decay traces of $^5D_0$ level Eu^{3+} ions in $Zr_{1-x}Eu_xTiO_4$ (x = 0.0001, 0.05) (λ_{ex} = 534 nm λ_{em} = 613 nm) at 300K and fitting curves.

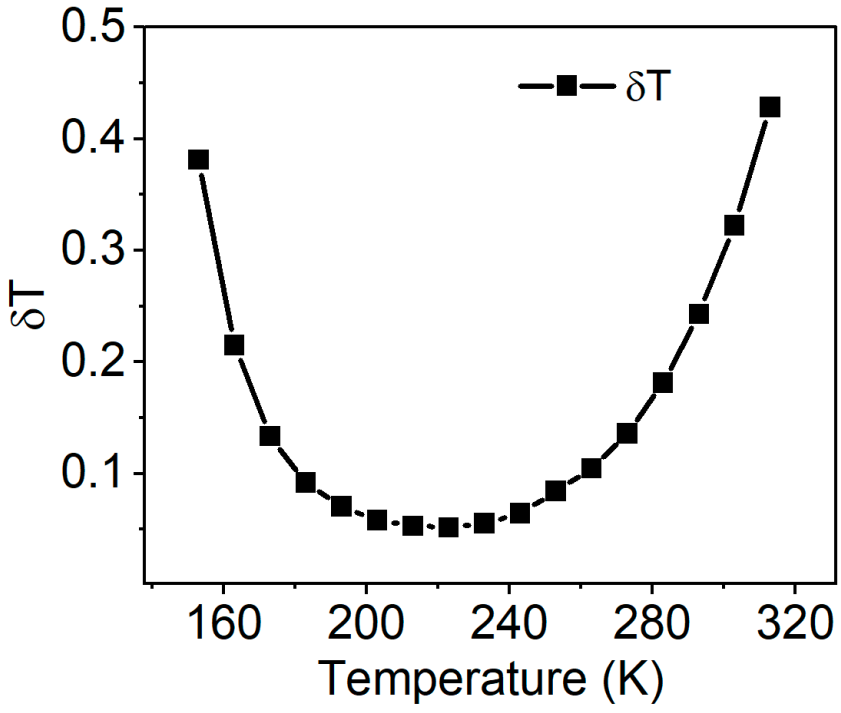

Figure S8. Temperature resolution δ_T of $Zr_{1-x}Eu_xTiO_4$ (x = 0.0001) temperature sensing material in the temperature range from 153K to 313K.

Table S1 The excitation and emission wavelengths used in decay kinetics measurements, lifetime constants and percentage of two components, reduced chi-squared value for exponential and biexponential fitting and average lifetimes in different samples ($Zr_{1-x}Eu_xTiO_4$)

Sample	Temperature (K)	Excitation wavelength (nm)	Emission wavelength (nm)	τ_1	τ_2	χ^2	Average lifetime[a]
$ZrTiO_4$	300	300	550	3.99 ns	31.26 ns	0.996	20.6 ns
$ZrTiO_4$	300	340	600	3.46 ns	29.88 ns	0.995	20.9 ns
$ZrTiO_4$	77	300	550	2.86 μs	20.92 μs	0.987	15.6 μs
$ZrTiO_4$	77	340	550	6.93 μs	43.44 μs	0.991	37.2 μs
$ZrTiO_4$	77	430	650	0.007 μs	0.60 μs	0.993	0.55 μs
$Zr_{1-x}Eu_xTiO_4$(x=0.0001)	300	534	613	0.35 ms	0.79 ms	0.999	0.69 ms
$Zr_{1-x}Eu_xTiO_4$(x=0.05)	300	534	613	0.73 ms	-	0.999	0.73 ms

[a] Average lifetime was calculated from the equation of $\bar{\tau} = \frac{A_1\tau_1^2+A_2\tau_2^2}{A_1\tau_1+A_2\tau_2}$