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Supporting Information

Reliable and stable ratiometric luminescent thermometer based on dual near-infrared emission in Cr^{3+}-doped $LaSr_2Ga_{11}O_{20}$ phosphor

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Experimental details

Synthesis

$LaSr_2Ga_{11}O_{20}:Cr^{3+}$ phosphors were prepared by conventional high-temperature solid-state reaction method. Stoichiometric amounts of La_2O_3, $SrCO_3$, Ga_2O_3, and Cr_2O_3 were weighed accurately and ground in an alumina mortar to form a homogeneous fine powder. The mixed powder was prefired at 900 ℃ in air for 2 h and cooled down to room temperature naturally. The pre-fired material was again ground to a fine powder. After that, the obtained powder was fired at 1400 °C for 6 h in air. After cooling down to room temperature naturally, the samples were ground again to acquire the final phosphors.

Characterization

The XRD measurements were done on a DMAX-2500PC Powder X-ray diffractometer (normal scanning rate: 10°/min, 10–70°; parameters for refinement: 0.02° step size, 10 s counting time, 10–70°). The TOPAS academic software was used for crystal structure refinement. The morphology and energy-disperse X-ray spectroscopy (EDS) of the as-synthesized phosphor were measured by a JSM-7800F field-emission scanning electron microscope (FE-SEM). The photoluminescence measurements were done using an FLS1000 spectrofluorometer (Edinburgh Instruments) loaded with a photomultiplier tube detector (PMT, 200–900 nm), and a 400 W Xe lamp was used as the excitation source. UH4150 spectrophotometer equipped with an integrating sphere was used to measure the diffuse reflection spectra. The low-temperature PL and PLE spectra (77 K) and temperature-dependent PL spectra (100–460 K range) were measured using an OptistatDN cryostat (Oxford Instruments) equipped with a MercuryiTC temperature-controlled system.

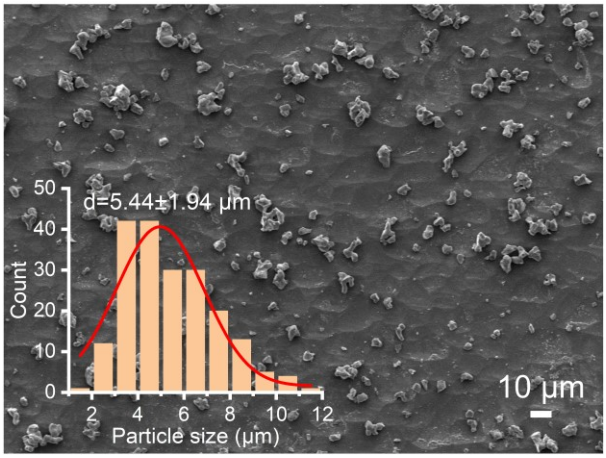

Fig. S1 SEM image of the $LaSr_2Ga_{11}O_{20}$:3%Cr^{3+} phosphor. The inset is particle size distributions of the phosphor.

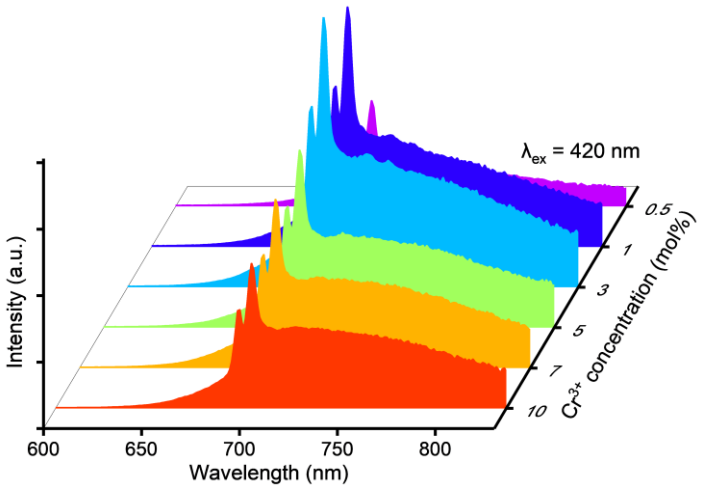

Fig. S2 Concentration-dependent emission spectra of $LaSr_2Ga_{11}O_{20}$:x%Cr^{3+} (x = 0.5, 1, 3, 5, 7, and 10) phosphors under 420 nm excitation.

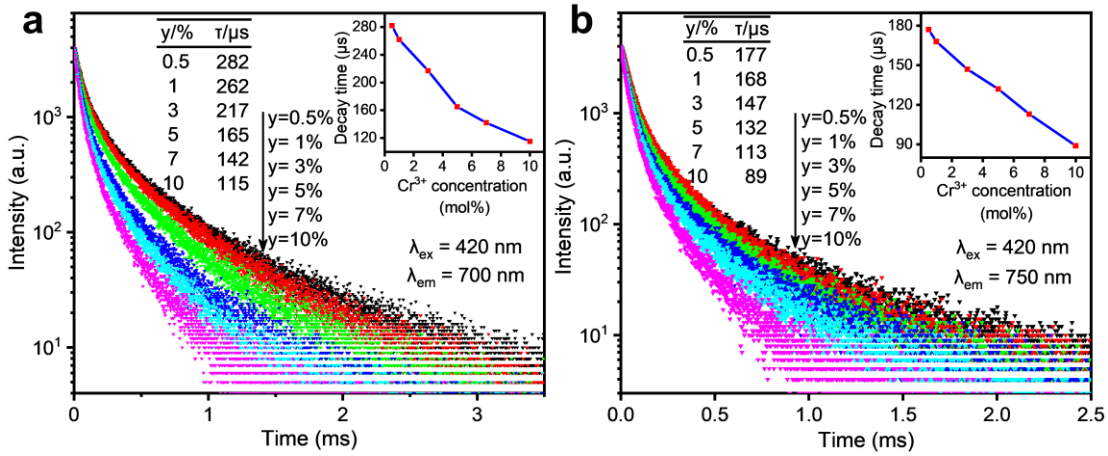

Fig. S3 Decay curves of $LaSr_2Ga_{11}O_{20}:Cr^{3+}$ phosphors under different Cr^{3+} doping concentrations under excitation at 420 nm, monitored at (a) 700 nm and (b) 750 nm, respectively. The upper inset is the dependence of the fluorescence lifetime on the Cr^{3+} concentration.

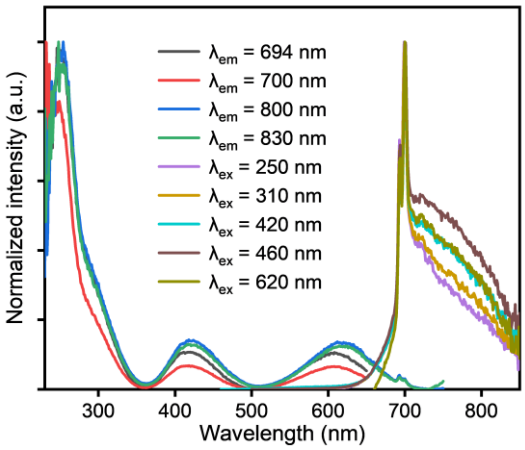

Fig. S4 Normalized photoluminescence and excitation spectra of $LaSr_2Ga_{11}O_{20}$:3%Cr^{3+} phosphor at room temperature.

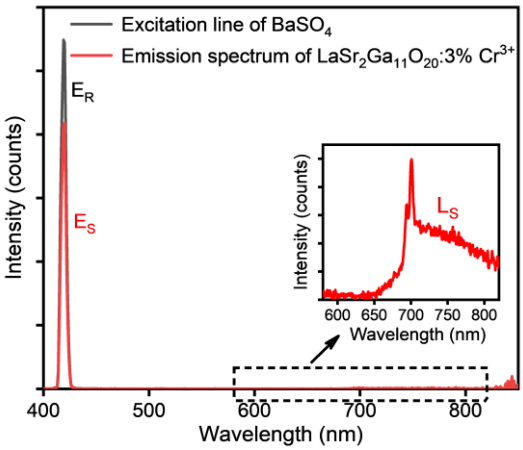

Fig. S5 Excitation line of $BaSO_4$ and emission spectrum of the $LaSr_2Ga_{11}O_{20}$:3%Cr^{3+} phosphor collected using an integrating sphere. The inset shows a magnification of the emission spectrum.

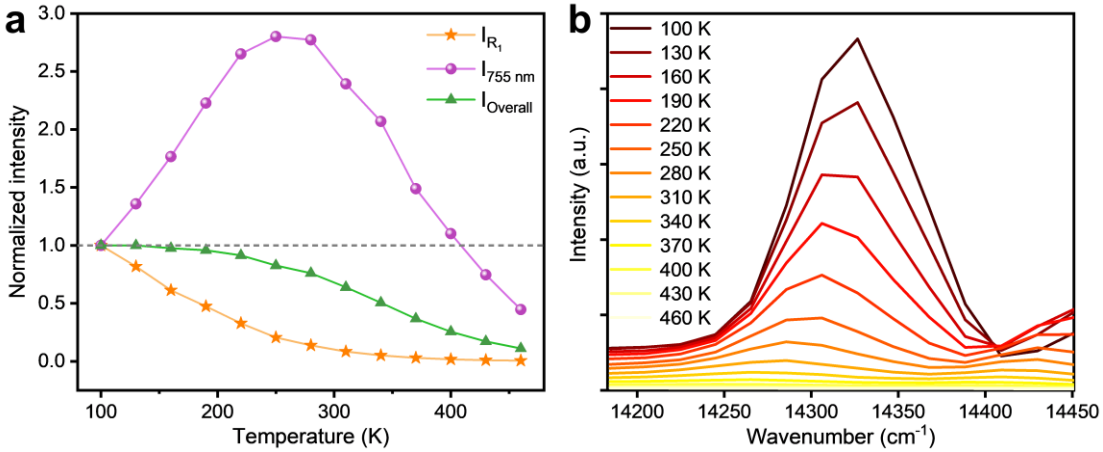

Fig. S6 (a) Temperature dependence of the PL intensity for both the $^2E \rightarrow {}^4A_2$ and $^4T_2 \rightarrow {}^4A_2$ transitions and the overall PL intensity. (b) Spectral shift of the R_1-line as a function of temperature in the 100–460 K range.

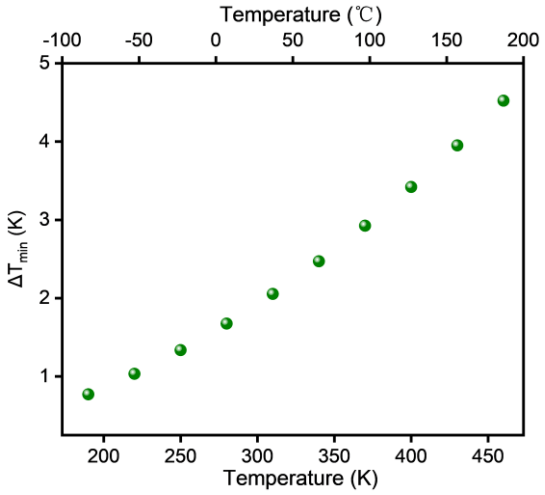

Fig. S7 Temperature dependence of thermal resolution ΔT_{min} in the range of linearity of the Boltzmann law.

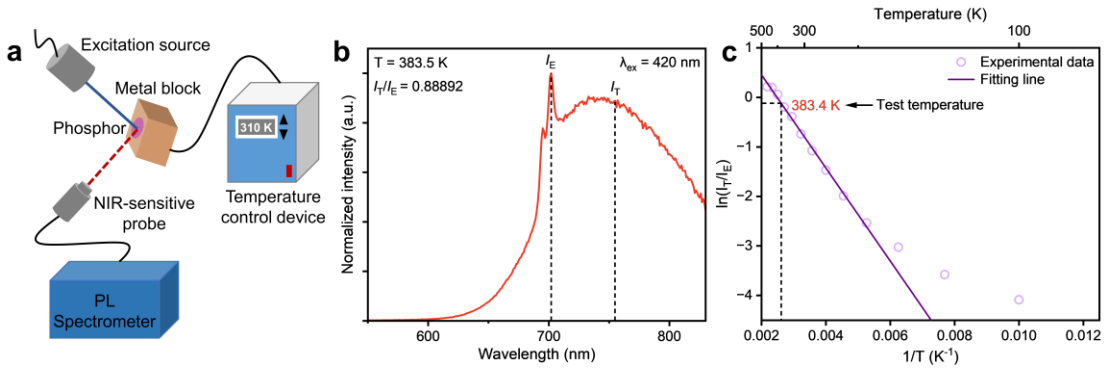

Fig. S8 (a) Demonstration of measuring the temperature of a metal block. The $LaSr_2Ga_{11}O_{20}$:3%Cr^{3+} phosphor was placed at the surface of a metal block. The temperature of the metal block was adjusted by a temperature control device. After holding for 5 min at a certain temperature, the PL emission spectrum of the phosphor was recorded with a spectrofluorometer. (b) PL emission spectrum of the $LaSr_2Ga_{11}O_{20}$:3%Cr^{3+} phosphor located on the surface when the metal block is heated to 383.5 K. (c) Test temperature of the metal block obtained by the I_T/I_E value from (b) and the plot of $\ln(I_T/I_E)$ versus T^{-1} to calibrate the $LaSr_2Ga_{11}O_{20}$:Cr^{3+} Boltzmann optical thermometer.

Table S1 Rietveld refinement parameters of the $LaSr_2Ga_{11}O_{20}$:3%Cr^{3+} phosphor.

Sample	$LaSr_2Ga_{11}O_{20}$:3%Cr^{3+}
Space group	I2/m
a (Å)	14.56872(17)
b (Å)	11.63243(13)
c (Å)	5.072881(58)
α=γ (°)	90
β (°)	91.260(2)
Volume ($Å^3$)	606.224(29)
R_{wp}	5.103%
R_p	3.511%
R_{exp}	0.723%

Table S2 Spectroscopic parameters of Cr^{3+} in $LaSr_2Ga_{11}O_{20}$.

Spectroscopic parameters	$LaSr_2Ga_{11}O_{20}:Cr^{3+}$
$E(^2E)$ (R-line energy)	14320 cm^{-1} (corresponding to 698.3 nm)
$E(^4T_2)_{ZPL}$ (ZPL energy of $^4T_2$)	14925 cm^{-1}
$E_{abs}(^4T_2)$ (absorption energy of $^4T_2$)	16313 cm^{-1} (corresponding to 613 nm)
E_{Stokes} (Stokes shift of the $^4T_2$-$^4A_2$ transition)	2776 cm^{-1}
$\hbar\omega$ (phonon energy of $^4T_2$)	226 cm^{-1}
$S(^4T_2)$ (Huang-Rhys parameter of $^4T_2$)	6.14
$S\hbar\omega$	1388 cm^{-1}