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Towards highly sensible Eu(III) thermal sensing at cryogenic temperatures using multiparametric thermometry

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Temperature is a crucial variable, not only from a thermodynamic perspective but also due to its vital role in a myriad of applications, including cutting-edge technologies such as superconductors and quantum information processing[1]. In this realm, temperature is critical for information retention, as devices in these fields often operate near or slightly above the liquid nitrogen temperature (77 K)[1]. Consequently, highly sensitive cryogenic temperature probes are in strong demand. Luminescent thermometry has emerged over the years as a promising contactless approach to probe temperature across various thermal ranges, relying on the thermal dependence of spectroscopic properties. Increasing the sensitivity of luminescent thermometers (LThs) is a non-trivial challenge, and this study aims to enhance sensitivity using a multiparametric approach (i.e., unifying two or more thermometric parameters). To substantiate this goal, the $SrY_2O_4:Eu^{3+}$ (2, 4, 6, and 8 at.%) phosphors were prepared by the modified Pechini method. The syntheses involved stoichiometric quantities of metal nitrate solutions, $Sr(NO_3)_3$, $RE(NO_3)_3$ (RE = Y^{3+}, Eu^{3+}), citric acid and D-sorbitol to form a polymeric resin, which was pre-heated at 350 °C for 3 h and annealed at 1100 °C for 5 h. X-ray diffraction (XRD) analysis and Rietveld refinement confirmed the formation of the orthorhombic SrY_2O_4 phase, enabling further investigation of the photophysical features. At low (10 K) and room temperature (298 K), the 4 at.% doped sample excelled among all samples regarding its emission spectra under 270 nm excitation, indicating the optimal concentration. When examining the emission profile of the 4 at.% sample as a function of temperature (10 – 310 K), distinct temperature dependencies were noted between the components of the $^5D_0 \rightarrow {}^7F_{0,1,2}$ emission bands, enabling a ratiometric approach yielding three different thermometric parameters values ($\Delta_{0\text{-}0}$, $\Delta_{0\text{-}1}$, and $\Delta_{0\text{-}2}$). Among these, $\Delta_{0\text{-}2}$ displayed the highest relative sensitivity (S_r of 0.25% K^{-1}) at 93 K with thermal uncertainty (δT) of 0.12 – 0.32 K. Although this is a reasonable result, one may wonder about the sensitivity achievable by unifying the three thermometric parameters. In this context, a 64-fold gain (16% K^{-1}), at 11 K, was achieved through multiple linear regression, with a δT of 2.1 K. Furthermore, a maximum relative sensitivity of 2.4% K^{-1} (9.6-fold enhancement) in the range 70 – 120 K was harnessed. These outcomes underscore the significance of this approach in harvesting the potential of LThs by improving the thermal sensing capabilities of simple thermometric systems.

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