Enhancing the performance of single-center lanthanide luminescence thermometer via dimensionality reduction

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As the foremost thermodynamic state variable, the precise measurement of temperature holds increasing significance in state-of-the-art technologies, such as the processing capabilities of networked devices [1]. The drive to develop more refined thermometers has spurred intense research on luminescence thermometers (LThs), where temperature-driven spectroscopic changes in luminescent probes yield thermal readouts [2]. Yet, while considerable efforts have been made to design novel probes to optimize LTh performance, few methodological advances have focused on improving classical thermometric essays. This shortfall prompted the present study, which pairs data analysis algorithms with multiple thermometric parameters to offer a forward-thinking perspective on post-processing methodologies. Specifically, we employed both linear and nonlinear dimensionality reduction (DR) techniques – multiple linear regression (MLR) and kernel principal component analysis (k-PCA) – on a proof-of-concept $SrY_2O_4:Tb^{III/IV}$(2 at.%),Eu^{III}(5 at.%) phosphor synthesized via an adapted Pechini route [3]. The algorithms were applied to a joined thermometric parameter consisting of the ratio between the thermally coupled Eu^{III}, i.e., $^5D_{0,1}$ (Δ) levels and the $^5D_0$ lifetime (τ). Compared to traditional fitting and integration methods, DR significantly improved thermometric performance, boosting the relative sensitivity (S_r) from 0.897% K^{-1} and 0.402% K^{-1} (using Δ and τ, respectively) to 3.68% K^{-1} with k-PCA. Concurrently, temperature uncertainty plummeted to 0.03 K, yielding high thermal resolution over the 77 – 500 K range. These findings unfold how advanced data analysis can extend the capabilities of LThs, paving the way for DR to manage multiple thermometric parameters and push luminescence thermometry toward unexplored possibilities.

Acknowledgements

References
[1] M. Suta, A. Meijerink, Adv. Theory Simul. 3, 12, 2020, 2000176.

[2] E. Ximendes, R. Marin, L.D. Carlos, D. Jaque, Light Sci. Appl. 11, 237, 2022.

[3] L.F. Saraiva, A.G. Bispo-Jr., A.L. Costa, F.A. Sigoli, S.A.M. Lima, A.M. Pires, Chem

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