Supplementary Information (SI) for Inorganic Chemistry Frontiers.

Supplementary information

Bi^{3+}-doped $BaMScO_4$ (M = Y, Gd) phosphors as multiple-mode optical thermometer for potential applications in optical thermometry and temperature imaging

Zhicheng Liao[a], Qian Zhang[b], Xiantao Wei[c], Liting Qiu[d], Yonghu Chen[*b], Min Yin[*b]

[a] School of Mathematics and Physics, Anqing Normal University, Anqin 246052, PR China

[b] Key Laboratory of Strongly-Coupled Quantum Matter Physics, Chinese Academy of Sciences, School of Physical Sciences, University of Science and Technology of China, Hefei 230026, PR China

[c] Physics Experiment Teaching Center, School of Physical Sciences, University of Science and Technology of China, Hefei 230026, PR China

[d] College of Intelligent Manufacturing, Putian University, Putian 351100, PR China

[*] **Corresponding authors.**

E-mail addresses: yhuchen@ustc.edu.cn (Y. Chen), yinmin@ustc.edu.cn (M. Yin)

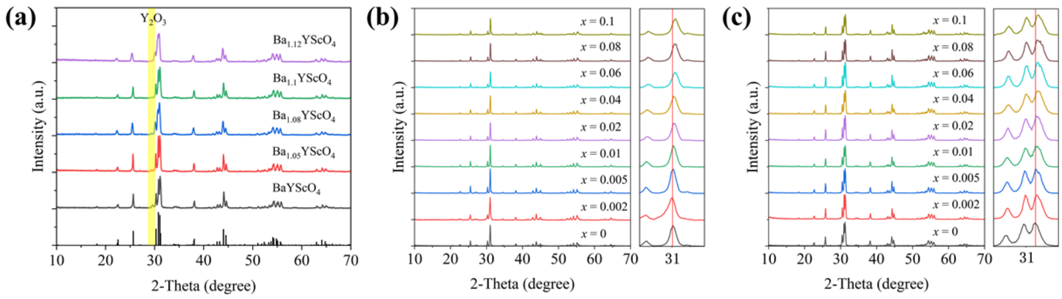

Fig. S1 (a) XRD patterns of $BaYScO_4$ with different $BaCO_3$ proportion. XRD patterns of (b) $BaGdScO_4$: $x$$Bi^{3+}$ (x = 0 – 0.1) and (c) $BaYScO_4$: $x$$Bi^{3+}$ (x = 0 – 0.1) samples.

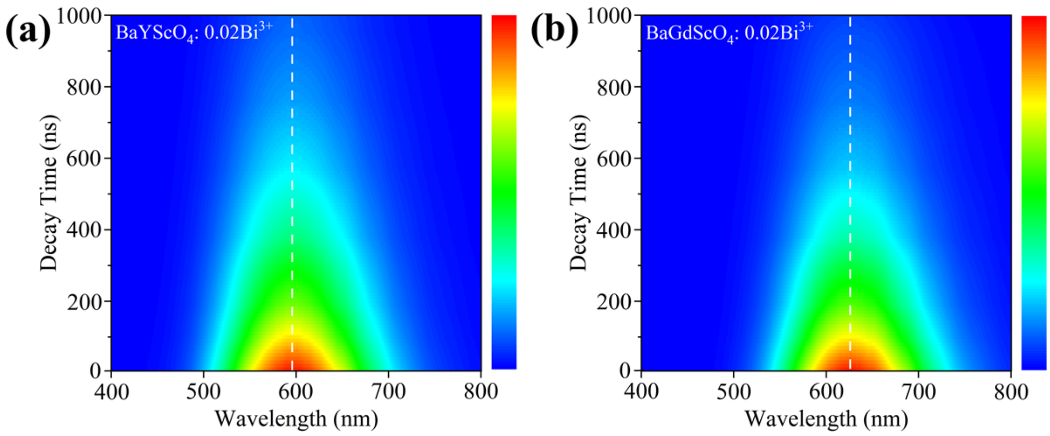

Fig. S2 Time-resolved photoluminescence spectra of (a) $BaYScO_4$: $0.02Bi^{3+}$ and (b) $BaGdScO_4$: $0.02Bi^{3+}$.

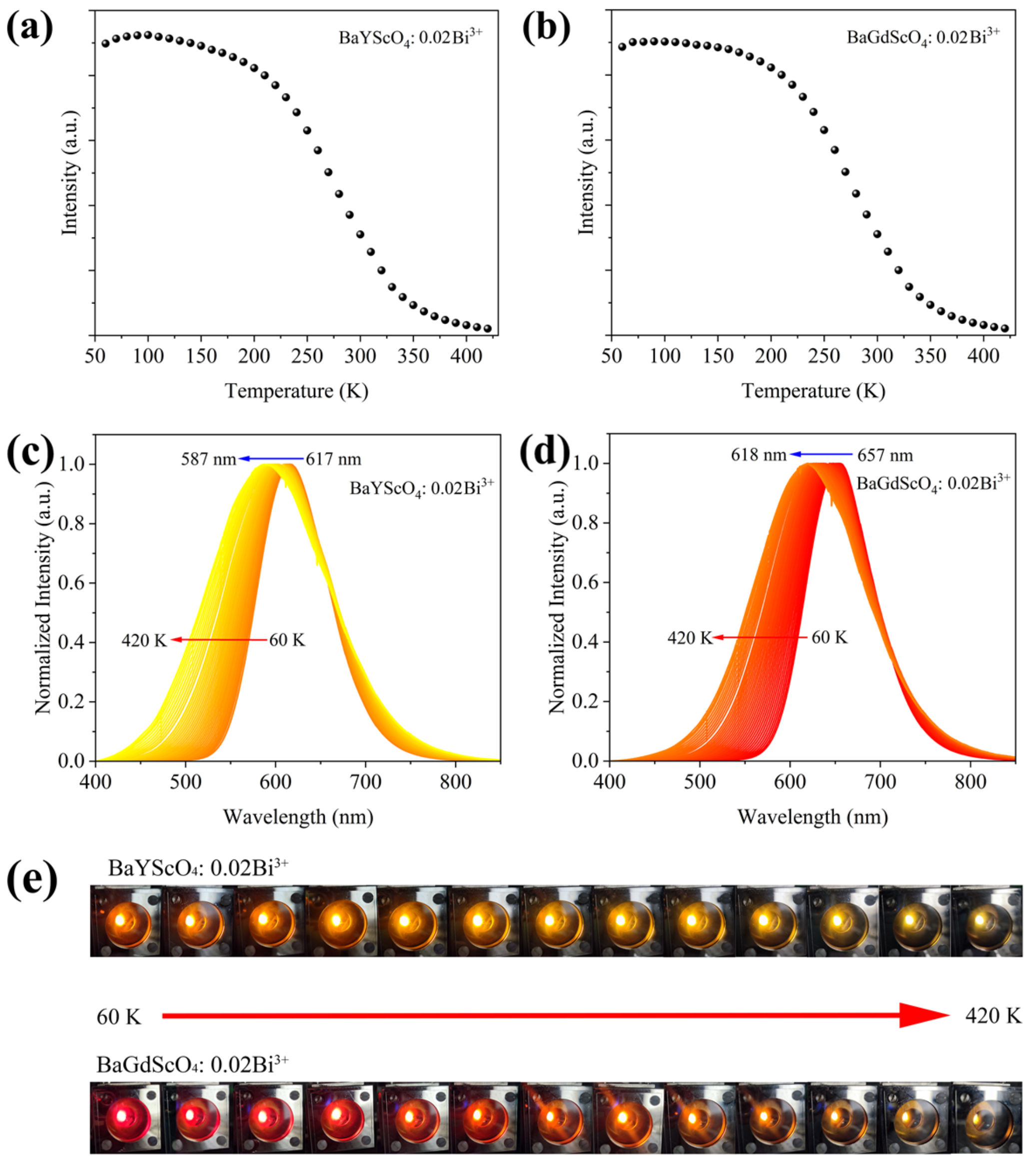

Fig. S3 The integrated PL intensity of (a) $BaYScO_4$: $0.02Bi^{3+}$ and (b) $BaGdScO_4$: $0.02Bi^{3+}$ in the temperature range from 60 to 420 K. Normalized PL spectra of (c) $BaYScO_4$: $0.02Bi^{3+}$ and (d) $BaGdScO_4$: $0.02Bi^{3+}$ in the temperature range from 60 to 420 K. (e) Digital photos of $BaYScO_4$: $0.02Bi^{3+}$ and $BaGdScO_4$: $0.02Bi^{3+}$at temperature ranging from 60 to 420 K under excitation of 355 nm laser.

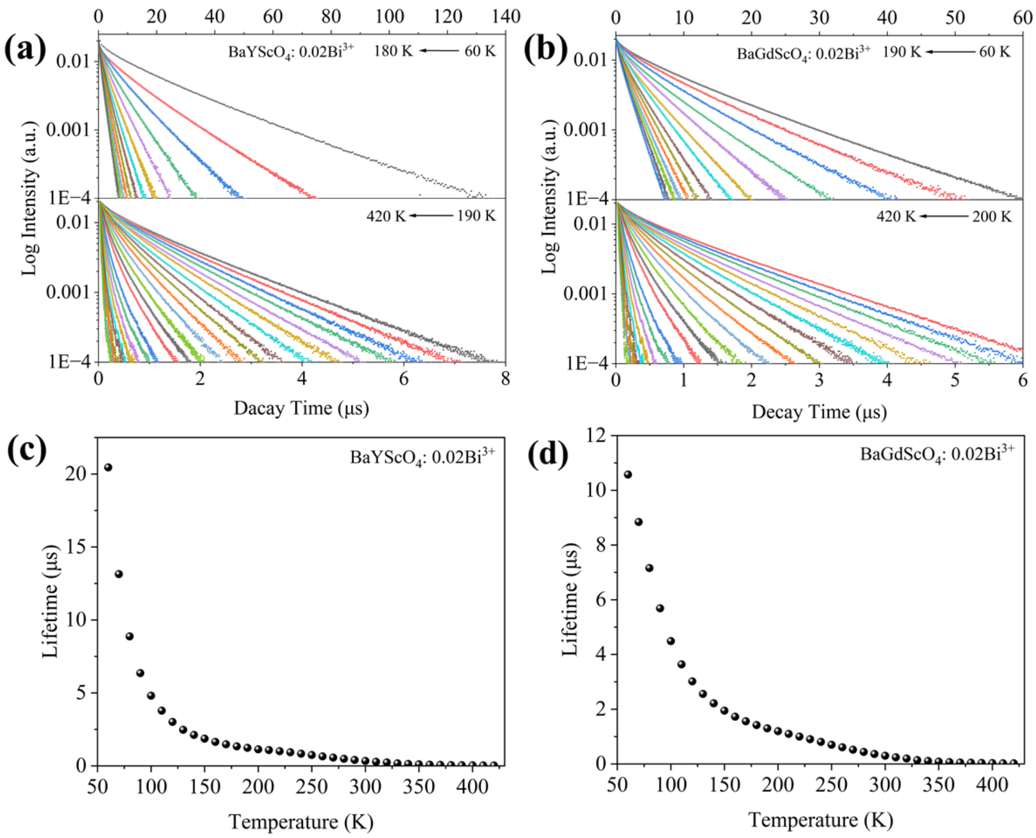

Fig. S4 Temperature-dependent fluorescence decay curves of (a) $BaYScO_4$: $0.02Bi^{3+}$ (λ_{em} = 600 nm) and (b) $BaGdScO_4$: $0.02Bi^{3+}$ (λ_{em} = 632 nm). The lifetime of (c) $BaYScO_4$: $0.02Bi^{3+}$ and (d) $BaGdScO_4$: $0.02Bi^{3+}$ in the temperature range from 60 to 420 K.

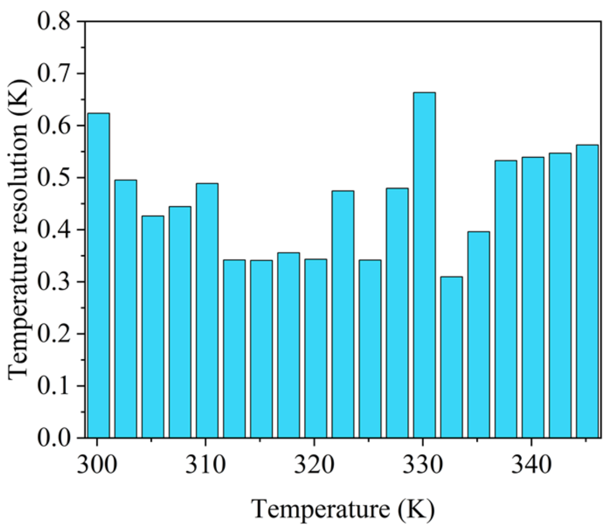

Fig. S5 Temperature resolution of the temperature sensing using $BaGdScO_4$: $0.02Bi^{3+}$ with time-resolved technique at different temperatures.

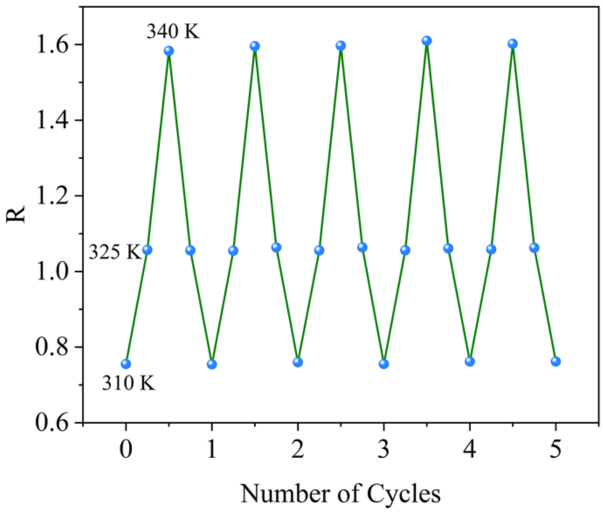

Fig. S6 The reproducibility measurement of the $R(T)$ values at 310 K, 325 K and 420 K for $BaGdScO_4$: $0.02Bi^{3+}$ under the temperature cycles of 310 K → 340 K → 310 K.

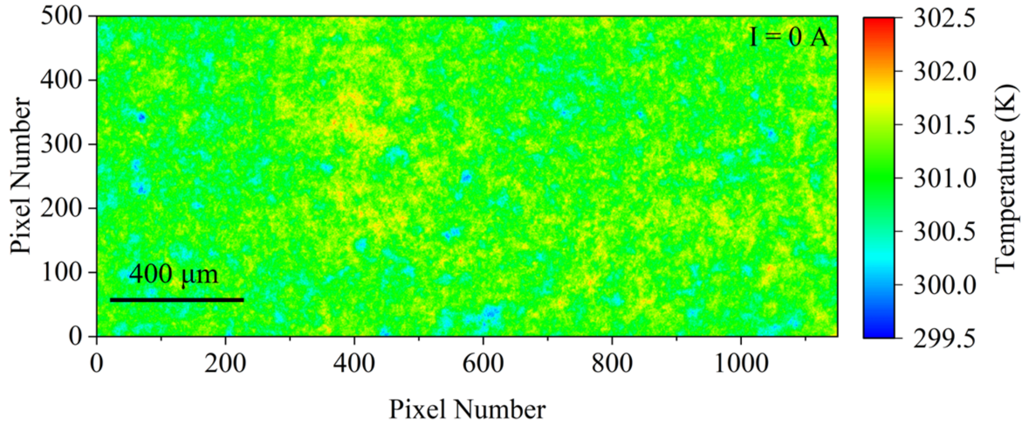

Fig. S7 The temperature distribution image of the PCB coated with the $BaGdScO_4$: $0.02Bi^{3+}$ phosphor without current.

Table S1 Main cell parameters obtained by refinement of $BaYScO_4$: xBi^{3+} (x = 0, 0.02) and $BaGdScO_4$: xBi^{3+} (x = 0, 0.02) samples

	$BaYScO_4$	$BaYScO_4$: $0.02Bi^{3+}$	$BaGdScO_4$	$BaGdScO_4$: $0.02Bi^{3+}$
a (Å)	8.8443	8.8409	8.9148	8.907
b (Å)	5.8914	5.8898	5.9198	5.9155
c (Å)	8.1181	8.1149	8.0724	8.0717
V (Å^3)	410.4132	409.9678	414.7512	413.9841
α = γ (°)	90	90	90	90
β (°)	104.0085	104.0187	103.203	103.2402
R_p (%)	7.41	8.35	7.82	8.17
R_{wp} (%)	9.33	11.88	10.3	11.08

Table S2 The thermal stability of some phosphors activated by Bi^{3+}

Composition	PL intensity at 423 K as a percentage of that at room temperature (%)	Reference
$Ba_2ZnGe_2O_7$: Bi^{3+}	138%@423 K	[1]
$SrGa_2B_2O_7$: Bi^{3+}	125%@423 K	[2]
$Ca_6BaP_4O_{17}$: Bi^{3+}	99%@423 K	[3]
Ba_2LuGaO_5: Bi^{3+}	80%@423 K	[4]
$Ca_3Lu_2Ge_3O_{12}$: Bi^{3+}	75%@423 K	[5]
$Ba_2Lu_5B_5O_{17}$: Bi^{3+}	70%@423 K	[6]
$SrGdGa_3O_7$: Bi^{3+}	67%@423 K	[7]
$Na_2Ca_3Ta_2O_9$: Bi^{3+}	66%@423 K	[8]
$LaCaGaO_4$: Bi^{3+}	65%@423 K	[9]
$LuMgGaO_4$: Bi^{3+}	64%@423 K	[10]
$KBaYSi_2O_7$: Bi^{3+}	62%@423 K	[11]
K_2ZrGeO_5: Bi^{3+}	47%@423 K	[12]
$Na_2Ca_3Nb_2O_9$: Bi^{3+}	about 42%@423 K	[8]
Sr_2GdAlO_5: Bi^{3+}	33%@423 K	[13]
K_2HfGeO_5: Bi^{3+}	30%@423 K	[12]
$BaLaGa_3O_7$: Bi^{3+}	28%@423 K	[7]
$SrLaGa_3O_7$: Bi^{3+}	27%@423 K	[7]
$CaLaGa_3O_7$: Bi^{3+}	25%@423 K	[7]
Sr_2GdGaO_5: Bi^{3+}	24%@423 K	[13]
$Ba_3SbAl_3Ge_2O_{14}$: Bi^{3+}, K^+	about 24%@423 K	[14]
$SrLaGaO_4$: Bi^{3+}	about 19%@423 K	[15]
$LuZnGaO_4$: Bi^{3+}	14%@423 K	[10]
$Ba_3LuGa_2O_{7.5}$: Bi^{3+}	15%@423 K	[16]
Sr_2LaGaO_5: Bi^{3+}	about 15%@423 K	[17]

Reference

[1] Y. Wei, H. Yang, Z. Y. Gao, X. H. Yun, G. C. Xing, C. G. Zhou and G. G. Li, Anti-thermal-quenching Bi^{3+} luminescence in a cyan-emitting $Ba_2ZnGe_2O_7$: Bi phosphor based on zinc vacancy, *Laser Photonics Rev.*, 2021, **15**, 2000048.

[2] S. Yang, Y. N. Wu, F. Y. Yue, R. J. Qi, B. Jiang, J. H. Wu, Y. Shen, C. G. Duan, Y. K. Shan, Q. B. Zhao and Y. F. Zhang, $MGa_2B_2O_7$: Bi^{3+}, Al^{3+} (M = Sr, Ba) blue phosphors with a quantum yield of 99% and negative thermal quenching, *Inorg. Chem. Front.*, 2021, **8**, 4257-4266.

[3] L. Liu, P. Dai and D. Wen, Ultra-narrow-band luminescence with spectral width down to 32 nm in bismuth-activated phosphate phosphors with superior thermal stability, *Mater. Today Chem.*, 2023, **30**, 101494.

[4] J. Y. Ding, X. F. Zhou, S. T. Lin, W. X. Zhang, L. Z. Shi, J. C. Zhou, S. S. Ye, D. W. Wu and Q. S. Wu, Novel orange-emitting phosphor Ba_2LuGaO_5: Bi^{3+} with high efficiency and thermal robustness induced by D-band emission, *J. Phys. Chem. C*, 2022, DOI: 10.1021/acs.jpcc.2c01442.

[5] S. S. Ye, H. Liu, Y. J. Wang, J. Lin, K. Zhong, J. Y. Ding and Q. S. Wu, Design of a bismuth-activated narrow-band cyan phosphor for use in white light emitting diodes and field emission displays, *ACS Sustainable Chem. Eng.*, 2020, **8**, 18187-18195.

[6] R. Y. Sun, C. Dou, F. You, J. Q. Zhao, J. Y. Lu, Y. Z. Yin, B. Teng, J. H. Li, S. J. Sun and D. G. Zhong, Investigation on $Ba_2(Y_{1-x}, Lu_x)_5B_5O_{17}$: y at.% Bi as a new type of N-UV excited high efficient blue phosphor for wLED, *Opt. Mater.*, 2022, **129**, 112542.

[7] Q. S. Wu, X. F. Zhou, S. S. Ye, J. Y. Ding and Z. B. Hu, The nature of Bi^{3+} luminescence in melilite-structure gallate $ABGa_3O_7$ (A = Ca, Sr, Ba; B = La, Gd), *Ceram. Int.*, 2023, **49**, 21060-21068.

[8] H. Z. Zhang, J. Zhang, Y. C. Su and X. M. Zhang, Metal to metal charge transfer induced efficient yellow/far-red luminescence in $Na_2Ca_3(Nb, Ta)_2O_9$: Bi^{3+} toward the applications of white-LEDs and plant growth light, *Adv. Opt. Mater.*, 2022, **10**, 2200150.

[9] Z. Lu, D. S. Sun, Z. Y. Lyu, S. D. Shen, P. C. Luo, S. Wei, L. H. Zhou and H. P. You, Novel color tunable $LaCaGaO_4$: Bi^{3+}, Eu^{3+} phosphors for high color rendering warm white LEDs, *J. Am. Ceram. Soc.*, 2023, **106**, 6617-6629.

[10] W. Y. Geng, X. F. Zhou, J. Y. Ding and Q. S. Wu, Unraveling the origin of broadband yellow emission in Bi^{3+}-doped $LuXnGaO_4$ (Xn = Mg, Zn) phosphors, *Dalton Trans.*, 2024, **53**, 3589-3598.

[11] H. W. Zhu, W. T. Zhang, Z. R. Yang, P. C. Zhang, Y. Huang, Enhanced blue emission of $KBaYSi_2O_7$:Bi^{3+} phosphors through partial substitution of Si^{4+} with Al^{3+} and Ge^{4+} for white light-emitting diodes, *J. Alloys Compd.*, 2024, **1004**, 175908.

[12] W. Y. Geng, J. P. Du, K. M. Hao, X. F. Zhou, J. Y. Ding, Q. S. Wu, Blue-emitting Bi^{3+}-doped K_2MGeO_5 (M = Hf, Zr) phosphors for full-spectrum WLED: Crystal structure, electronic structure and luminescent properties, *J. Lumin.*, 2024, **269**, 120461.

[13] P. X. Gao, Q. Li, S. Y. Li, S. J. Gai, Y. N. Li, Y. B. Ma, Z. T. Zhang, M. S. Molokeev, Z. Zhou and M. Xia, Multiple strategies to approach high-efficiency luminescence controllable in blue/cyan/green-emitting Bi^{3+}-activated phosphors, *J. Phys. Chem. C*, 2022, DOI: 10.1021/acs.jpcc.2c02560.

[14] H. H. Fei, B. L. Jing, J. Han, K. A. Shan, D. M. Cheng, X. Q. Xu, X. M. Zhang and J. Wang, Crystal structure, Bi^{3+} yellow luminescence, and high quantum efficiency of $Ba_3SbAl_3Ge_2O_{14}$: Bi^{3+} phosphor for white light-emitting diodes, *Inorg. Chem. Front.*, 2024, **11**, 2616-2625.

[15] S. Wu, Y. Fu, Q. Liu, P. Xiong, D. Wang, G. Zhang, S. Yuan and Y. Chen, Obtain full visible

spectrum light-emitting diode illumination via bismuth-activated cyan phosphors, *Mater. Today Chem.*, 2022, **23**, 100754.

[16] R. Z. Liu, H. Y. Wu, S. W. Wang, W. H. Yuan, S. Zhang, R. Pang, L. H. Jiang, D. Li, C. Y. Li and H. J. Zhang, $Ba_3LuGa_2O_{7.5}$: Bi^{3+} phosphors with potential application in full-spectrum WLEDs and temperature sensing, *J. Mater. Chem. C*, 2023, **11**, 2653-2663.

[17] S. Wu, Q. Liu, M. G. Brik, P. X. Xiong, D. Wang, G. X. Zhang and Y. Chen, Bi^{3+}/Mn^{4+} co-doped dual-emission phosphors for potential plant lighting, *J. Am. Ceram. Soc.*, 2022, **105**, 5793-5806.