Filter-Free Luminescence Thermometry based on Mn^{2+} Luminescence

Y. Abe[1,#], M. Szymczak[1], J. Zeler[2], L. Marciniak[1]

[1]Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Okólna 2, 50-422 Wrocław, Poland
[2]Faculty of Chemistry, University of Wrocław, 14 F. Joliot-Curie Street, 50-383 Wrocław, Poland

Luminescent thermometry, which uses the spectroscopic properties of phosphor materials to detect temperature-dependent changes, enables to sense not only point temperature but also two-dimensional temperature distributions. Two-dimensional thermal imaging requires appropriate band-pass optical filters to record luminescence signal in selected spectral ranges. However, the loss of temporal resolution due to the exchanging optical filters is the notable limitation of this approach. To overcome this limitation, a filter-free imaging strategy based on the RGB channels of a standard camera has recently been proposed[1]. Single photograph provides spatially resolved intensity maps for the red (R), green (G), and blue (B) channels, allowing to achieve fast, low-cost, and real-time thermal imaging.

In this study, we introduce the filter-free thermal imaging by utilizing Mn^{2+} and Ce^{3+} emissions. Ce^{3+} ions works as a sensitizer to enhance emission efficiency of Mn^{2+} ions resulting from spin-forbidden electronic transitions through $Ce^{3+}\rightarrow Mn^{2+}$ energy transfer[2]. On the other hand, Mn^{2+} emission band can be modulated through the crystal field strength. We observed two unusual thermal effects of Mn^{2+} emissions: (i) a temperature-induced blueshift of the ${}^4T_1\rightarrow{}^6A_1$ emission band of Mn^{2+} ions, and (ii) thermally assisted population of the ${}^4T_1$ excited state via optical trap sites. These combined processes result in a simultaneous blueshift and thermal enhancement of the Mn^{2+} emission band. Consequently, the luminescence signals in the G channel increases with temperature, while the emission intensity in B channel decreases. The synergy of these thermal behaviors of Mn^{2+} ions enables investigated $Ca_{19}Zn_2(PO_4)_{14}$:Mn^{2+}, Ce^{3+} to demonstrate not only ratiometric readout schemes, but also sensitive filter-free thermal imaging. Based on the comprehensive spectroscopic analysis of Mn^{2+} and Ce^{3+}-doped $Ca_{19}Zn_2(PO_4)_{14}$ as a function of dopant concentration and temperature, the potential of this phosphors for applications in filter-free thermal imaging is demonstrated in this work.

Acknowledgments: This work was supported by the Foundation for Polish Science under First Team FENG.02.02-IP.05-0018/23 project with funds from the 2nd Priority of the Program European Funds for Modern Economy 2021-2027 (FENG).

[1] W. Piotrowski, L. Marciniak *et al*. (2020) Appl. Mater. Interfaces, 12, 44039–44048.
[2] M.A. Mickens *et al*. (2014) J. Lumin., 145, 498–506.

corresponding author: y.abe@intibs.pl
co-authors: m.szymczak@intibs.pl, justyna.zeler@chem.uni.wroc.pl, l.marciniak@intibs.pl