Temperature-dependent Cathodoluminescence: Quantifying Thermal Quenching at the Microscopic Level

L.I.D.J. Martin[1,2]*, D. Poelman[1,2], P.F. Smet[1,2]
[1]LumiLab, Department of Solid State Sciences, Ghent University, Ghent, Belgium
[2]Center for Nano- and Biophotonics (NB-Photonics), Ghent University, Ghent, Belgium
*Lisa.Martin@Ugent.be

A cathodoluminescence (CL) detector attached to a scanning electron microscope (SEM) is capable of producing images with high spatial resolution, which provide information on defects in semiconductors or the age and provenance of minerals. SEM-CL can be applied to a variety of materials, especially to those compounds which are intended to emit light. These luminescent materials are ideally suited for a microscopic investigation by SEM-CL (Fig. 1).

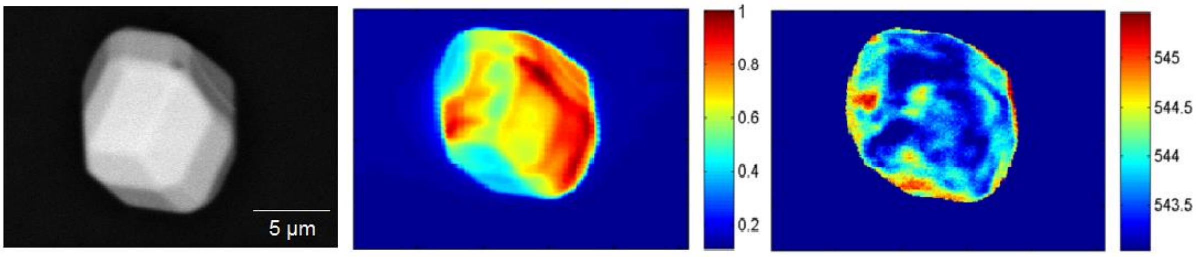

Figure 1: Backscattered electron image (left), normalized total intensity (center) and emission barycenter in nm (right) derived from a spectrally resolved CL mapping of $Lu_3Al_5O_{12}$:Ce at -25°C.

Luminescent materials, also known as phosphors, find their main application in white light emitting diodes (LEDs). LEDs are rapidly replacing incandescent and fluorescent lamps in general lighting, as well as in display back lighting. White LEDs consist of a blue emitting LED chip and one or more phosphor materials which convert part of the blue light to longer wavelengths. These phosphors should retain efficiency and color [1] while operated well above room temperature. Therefore it is important to know how temperature affects the emission spectrum and intensity.

Thermal quenching is generally measured on bulk material, whereas in this work the thermal behavior is evaluated at microscopic level by SEM-CL. A heating stage using a Peltier element is used, making it possible to investigate the sample’s behavior between -25°C and 125°C. If the material is inhomogeneous or consists of multiple phases, different thermal quenching temperatures can occur in a single sample (or even within a single phosphor particle) resulting in spectrum changes upon changing temperatures [2].

With the addition of an energy-dispersive X-ray detector (EDX) the local composition and dopant concentration can be studied simultaneously. Correlating structural, compositional and luminescent information allows for identification of non-uniform doping or impurity phases, which can be used to improve synthesis methods and possibly also the overall performance of the phosphor.

[1] P.F. Smet, A.B. Parmentier, and D. Poelman, Journal of the Electrochemical Society **158**, R37-R54 (2011).
[2] P.F. Smet, J. Botterman, A.B. Parmentier, and D. Poelman, Optical Materials **35**, 1970–1975 (2013).