Experiment Brief

Monarc system

Title

Spectroscopic time-resolved cathodoluminescence using a conventional scanning electron microscope (SEM)

Gatan Instrument Used

The Monarc® Pro system offers the most complete analysis of cathodoluminescence (CL) emissions and empowers all users to capture the highest quality data, whether novice or expert.

Background

The temporal evolution of luminescence from semiconductor materials, phosphors, and geological samples can reveal important properties of the luminescence mechanism. The luminescence decay constant, τ, can be measured and, typically, varies as a function of emission wavelength. Determination of τ can reveal recombination dynamics relevant to stress and strain, mobility, and diffusion length. In an electron microscope, investigation of τ is challenging experimentally due to the requirement for a pulsed electron beam with ultra-fast on/off transitions; possible solutions include ultrafast beam blanking and photoemission-induced electron pulses. However, these schemes are suitable for a very limited range of specialized microscopes.

Materials and Methods

In this study, we use the electron beam of an SEM to excite a commercially available ZnS: Cu, Al-based inorganic phosphor particle, and use the positioning of the electron beam as the on/off excitation switch. During an electron beam scan, the specimen is excited when the electron beam is located at the particle, and excitation is switched off as the electron beam is moved to the non-luminescent substrate. The luminescence decay from a particle was measured with the Monarc Pro CL system and DigiScan™ 3 with a temporal resolution of ≥100 ns (based on the dwell time per pixel defined in the electron beam scan). A wavelength-filtered spectrum image of 60, 5 nm bandpass slices were captured over the wavelength range 400 – 700 nm using DigitalMicrograph® software, Figure 1. The spectral decay was extracted from 0 – 185 µs, and the intensity, I, decay was determined as a function of time, t, and wavelength, λ, using a two-component decay constant, τ, according to:

$$I(\tau_1, \tau_2, \lambda) = I(\lambda)_1 \exp(-t/\tau_1(\lambda)) + I(\lambda)_2 \exp(-t/\tau_2(\lambda)) + C$$

The decay constants, τ_1 and τ_2 (displayed in Figure 2), and at peak emission 515 nm, were approximately 12 and 45 µs, respectively.

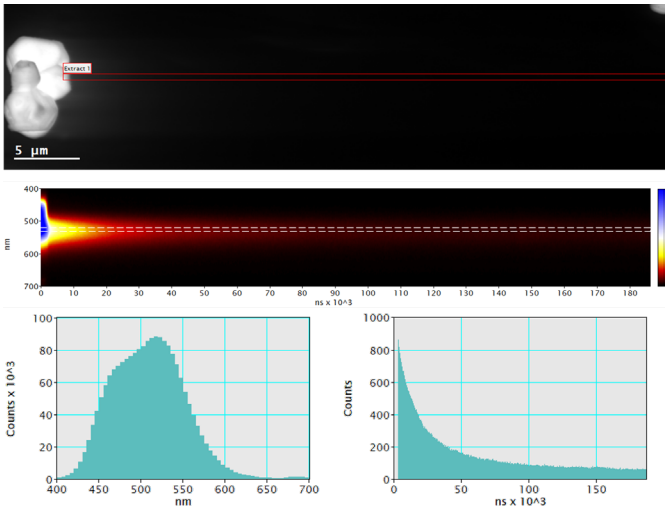

Figure 1. (top) Unfiltered CL image with the (red rectangle) decay extraction region indicated. (middle) Streak map from luminescent phosphor particle demonstrating luminescence decay. (bottom left) Cumulative CL spectrum and (bottom right) luminescence decay from 525 ± 10 nm.

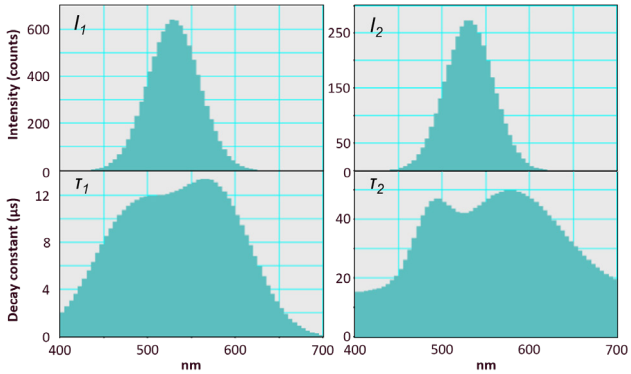

Figure 2. Figure 2. Fit results including (top left) $I_1(\lambda)$, (top right) $I_2(\lambda)$, (bottom left) $\tau_1(\lambda)$, and (bottom right) $\tau_2(\lambda)$.

Summary

Luminescence decay was spectroscopically observed with ≥100 ns resolution for a commercially available ZnS:Cu, Al-based inorganic phosphor using a PMT detector. This approach afforded spectroscopic determination of two lifetime components of approximately 12 and 45 µs at peak emission. This demonstrates the capacity for spectroscopic CL imaging to extend to evaluation of luminescence decay for phosphorescent lifetimes.

Gatan, Inc. is the world's leading manufacturer of instrumentation and software used to enhance and extend electron microscopes—from specimen preparation and manipulation to imaging and analysis.

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