Cathodoluminescence Characterization of Luminescent Fluoride Nanoparticles

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Fluoride-based rare-earth-doped nanoparticles have attracted considerable attention due to their high luminescence efficiency, chemical stability, and suitability for applications involving ionizing radiation [1]. In particular, $Ce_xLa_{1-x}F_3:Tb^{3+}$ nanoparticles represent a promising class of materials for scintillation-based imaging and electron-beam-driven luminescence techniques. For such applications, a detailed understanding of their behavior under electron excitation is essential, making cathodoluminescence (CL) a highly relevant characterization method.

We present a CL study of $Ce_xLa_{1-x}F_3:Tb^{3+}$ nanoparticles, focusing on their response to electron-beam excitation. Continuous irradiation with a high current density of 23.5 A·m^{-2} was applied for up to 200 s, during which the evolution of the CL spectra was monitored in situ. While pronounced changes in the CL intensity were observed, the spectral shape remained unchanged, indicating radiation-induced modifications affecting excitation or recombination efficiency rather than the emitting centers themselves.

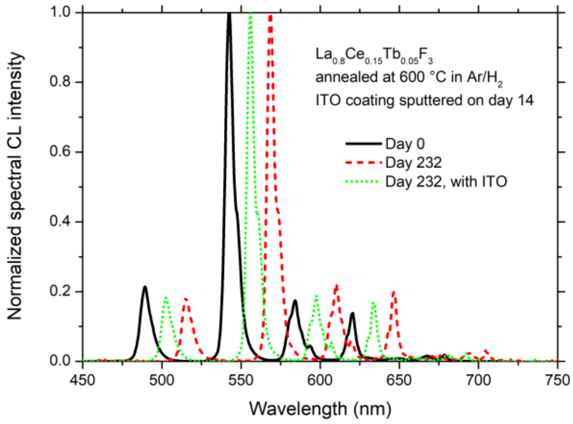

Fig. 1: Normalized CL spectra of $La_{0.8}Ce_{0.15}Tb_{0.05}F_3$ nanoparticles measured early after preparation (Day 0) and after 232 days of storage, for uncoated samples and samples coated with a 50 nm indium-tin oxide (ITO) layer sputtered on day 14.

Long-term stability effects were investigated using $Ce_{0.15}La_{0.8}Tb_{0.05}F_3$ nanopowders, which were measured initially and re-examined after half year of storage under ambient conditions. A red shift of the CL emission was detected, amounting to 13 nm for samples coated with a 50 nm indium–tin oxide (ITO) layer and up to 26 nm for uncoated samples (Fig. 1). These shifts are discussed in terms of surface-related processes, such as interaction with atmospheric moisture and gradual modification of the near-surface electronic structure.

Additionally, pulsed CL decay measurements at three orders of magnitude lower current densities in the temperature range 100–500 K were performed to elucidate recombination dynamics and thermal quenching mechanisms. Overall, this work demonstrates how CL characterization provides unique insight into the stability, excitation mechanisms, and environmental sensitivity of $Ce_xLa_{1-x}F_3:Tb^{3+}$ nanoparticles, supporting their further development for electron-driven luminescence applications.

1. X. Lytvynenko, et al. "Composition-dependent properties of $Ce_xLa_{0.95-x}Tb_{0.05}F_3$ nanopowders tailored for X-ray photodynamic therapy and cathodoluminescence imaging," *Radiat. Meas.* **189** (2025) 107536.

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