

Recent Advances in Luminescence Studies of Single Crystals and Single-Crystalline Phosphors Using Synchrotron Radiation

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Substantial differences in preparation methods lead to pronounced variations in the luminescent properties of bulk crystals and single-crystalline film (SCF) phosphors. These variations originate from differences in the types, concentrations, and distributions of intrinsic defects, as well as from the distribution of dopant ions over cation sites and their interactions with defect- and dopant-related centers in different crystalline forms of the same material.

In bulk oxide crystals grown from high-temperature melts, defect centers such as oxygen and cation vacancies, antisite defects, and their aggregates can contribute significantly to both the intrinsic luminescence of the host matrix and dopant emission. This often obscures the intrinsic luminescence of the host and alters the emission characteristics of dopants. In contrast, single crystalline oxide films grown by low-temperature liquid-phase epitaxy (LPE) from fluxes exhibit a substantially reduced concentration of intrinsic defects. Moreover, the preferential occupation of cation sites by dopant ions may differ markedly between films and bulk crystals. However, LPE-grown films may incorporate residual flux-related impurities, which also can act as emission or trapping centers and thus influence luminescence.

Therefore, detailed comparative study of bulk crystals and SCFs very often enables a reliable distinction between intrinsic, dopant-related, and defect-related luminescence in complex oxides. Furthermore, the combined application of optical spectroscopy, electron paramagnetic resonance (EPR), and luminescence spectroscopy under synchrotron radiation (SR) excitation, particularly in the excitonic and interband transition energy ranges, provides a powerful approach for such analysis and allows for a consistent comparison of luminescent properties across different crystalline forms.

The aim of this presentation is to demonstrate representative examples comparing the structure of luminescent centers in bulk crystals and single-crystalline film phosphors: Mg²⁺-doped Al₂O₃ (sapphire), Eu³⁺-doped Lu₂O₃ (lutetia), Ce-doped Lu_{1-x}Gd_xAlO₃ and Gd_{1-x}Y_xAlO₃:Ce mixed perovskites, as well as Sc³⁺-doped Lu₃Al₅O₁₂ garnet. The analysis is based on conventional spectroscopic techniques combined with time-resolved luminescence spectroscopy using VUV excitation at the P66 beamline (PETRA III, DESY, Germany).

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