

Mechanisms of optically stimulated luminescence in BaF₂

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Optically stimulated luminescence (OSL) is the light observed after a material has been exposed to ionizing radiation and optical stimulation is used to excite electrons and/or holes trapped in metastable states within the material's bandgap. In extrinsic scintillators, OSL has been shown to involve the same luminescence centers introduced for scintillation, such as rare-earth dopants [1]. In contrast, the electron and hole trapping and luminescence mechanisms responsible for OSL in intrinsic scintillators remain to be further explored [2]. In this work, we investigate these mechanisms using BaF₂, a material of interest for fast timing applications. Scintillation in BaF₂ is attributed to the formation and radiative decay of self-trapped excitons (STEs), in which a self-trapped hole in a V_K or H center configuration forms a bound state with an excited electron [3]. The non-radiative decay of the STE is known to generate stable defects in the crystal lattice [4]. We propose that these defects act as the electron and hole traps responsible for OSL in BaF₂, and that optically stimulated luminescence occurs through the re-formation and subsequent radiative decay of the STE.

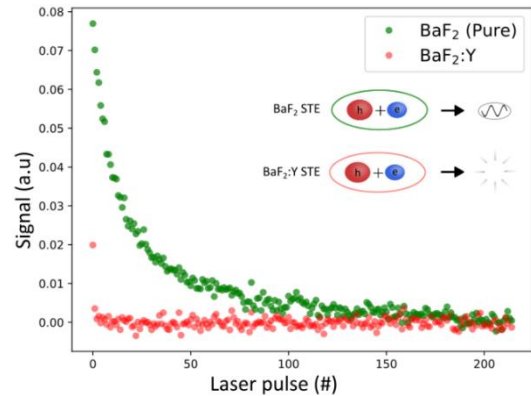


Figure 1: Measured OSL signal from two different BaF₂ samples with or without Y-doping after 1 s Sr-90 irradiation. The STE emission is inhibited by Y-doping as is seen by the low, constant value. Backgrounds for the respective samples have been subtracted. Spectral window between 250-400 nm.

Results are shown in figure 1 suggesting that OSL comes from STEs as for scintillation. Here, two samples of BaF₂ made by Epic Crystal with or without yttrium-doping have been irradiated and a subsequent OSL experiment is performed. The addition of yttrium into the lattice is known to suppress the STE radiative yield [5], and the lack of signal from the doped sample indicates that OSL emission happens through radiative STE decay.

By measuring spectrally and temporally resolved emission from both scintillation and OSL, we aim at understanding the similarities and differences between the underlying mechanisms of the processes. Spectral results show that the emission of both scintillation and OSL have the same shape, but interestingly the peak wavelength of the latter is redshifted by about 20 nm. Furthermore, the process of OSL is seen to be slower than scintillation with longer rise- and decay times by factors of around 10 and 30, respectively, which indicates a different emission process than scintillation. Clarifying the OSL process adds fundamental insight and possibly allows manipulation of defects to increase signal.

1. M.L. Jensen. *et al.*, "Optically stimulated luminescence in state-of-the-art LYSO:Ce scintillators enables high spatial resolution 3D dose imaging", *Sci. Rep.* **12**, 8301 (2022).
2. C.L. Nielsen. *et al.*, "The origin of room-temperature self-trapped-exciton emission in LiF nanoparticles", *Phys. Rev. Materials* **7**, 106001 (2023)
3. P.A. Rodnyi, "Electron-hole and exciton processes in CaF₂, SrF₂, and BaF₂ crystals (Review)", *Phys. Solid State*, **66**, 2 (2024)
4. K.S. Song, R.T. Williams, "Self-Trapped Excitons", Springer Berlin, Heidelberg (1996)
5. J. Chen *et al.*, "Slow Scintillation Suppression in Yttrium Doped BaF₂ Crystals", *IEEE Trans. Nucl. Sci.*, **65**, 8 (2018)