Low-temperature afterglow investigations of GGAG:Ce(4 mol%) scintillators synthesized via solvothermal method

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Recent advances in scintillator materials and additive manufacturing have driven significant interest in nanosized GGAG:Ce–based 3D-printed composite scintillators for high-resolution X-ray imaging applications [1]. In such 3D-printing approaches, inorganic nano/micro-scale scintillator powders are incorporated into either filament-based or curable resin matrices. In this work, GGAG:Ce nanoscintillator powders were synthesized via the solvothermal (ST) method, and their thermally stimulated luminescence (TSL), afterglow, and radioluminescence properties were systematically investigated. The results were compared with GGAG:Ce powders prepared by the conventional solid-state (SS) reaction under soft X-ray excitation. In this study, SS synthesis was carried out with 0.5 at.% Ce and a Ga/Al ratio of 3/2, sintered in argon, while S.T employed 4 mol% Ce with a Ga/Al ratio of 3.2/1.8, sintered in nitrogen. Phase purity was confirmed by X-ray diffraction, whereas field-emission scanning electron microscopy revealed distinct morphological differences, the ST sample exhibited particle sizes around 120 nm, whereas the SS sample showed larger particles averaging 280 nm. Energy-dispersive X-ray spectroscopy verified the presence of all constituent elements in the synthesized powders. Radioluminescence spectra recorded over the temperature range of 20–300 K exhibited bright Ce^{3+} emission at around 2.2 eV for both samples with the ST prepared sample showing a relative scintillation yield of approximately 66% compared to the SS synthesized sample. Afterglow measurements revealed a rapid decay (~30 s) with residual emission below 1%, confirming a fast time response suitable for fast response imaging attributed to the presence of trap states. This is further confirmed by TSL experiments reporting two main bands related to Ce^{3+} emission in the glow curve: in the GGAG:Ce prepared by ST synthesis, the first band is composite and extends in the 50-120 K region, whereas the high temperature one is sharper and peaked at around 280 K. The SS method led to a similar glow curve shape related to Ce^{3+} emission with two bands at around 60 K and 240 K, but showed a plethora of TSL peaks below 120 K related to defects emission in the 3–5 eV region, possibly responsible for additional trap states affecting the time response of the material. Overall, these results highlight the critical role of synthesis method, compositional tuning (Ga/Al ratio) and ambient sintering conditions in influencing the trap dynamics, optical transparency and imaging resolution in GGAG:Ce based scintillators [2].

1. Oad, N. et al., “X-ray imaging using 3D-Printed thin films of solvothermal GGAG:Ce^{3+} powder” *Optical Materials* 169 (2025) 117611.
2. Huang, X. et al., "Ultrafast GGAG: Ce X-ray scintillation ceramics with Ca^{2+} and Mg^{2+} co-dopants" *Ceramics International* 48 (2022) 23571-23577.