A Pulse Shape Discrimination Performance of Garnet-Based Composite Scintillators in α/β/γ Mixed Fields

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Composite scintillators based on epitaxial structures of garnet compounds were developed for the simultaneous registration of mixed radiation fluxes [1]. In the present work, we investigated a GAGG:Ce ($Gd_3Al_{2.5}Ga_{2.5}O_{12}$:Ce) bulk single crystal (SC) as a substrate, as well as two double-layered structures: TbAG:Ce SCF/GAGG:Ce SC and TbAG:Ce,Mg SCF/GAGG:Ce SC. These structures comprise single-crystalline films (SCFs) grown on GAGG:Ce substrates by the liquid phase epitaxy (LPE) method. Previously measured scintillation time profiles for these samples [2] showed distinct scintillation-decay time shapes in TbAG:Ce SCF/GAGG:Ce SC and TbAG:Ce,Mg SCF/ GAGG:Ce SC samples, especially in that with SCF co-doped with Mg^{2+}, see Fig. 1.

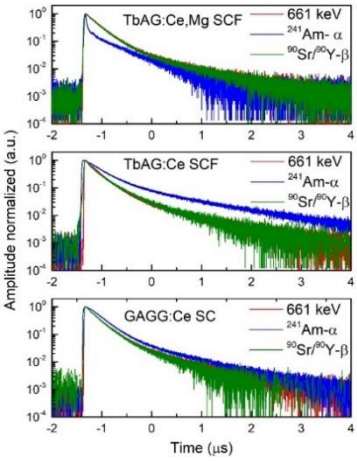

Fig. 1 Light pulse shapes of the tested samples for α, β, and 662-keV γ-rays.

For the first time, a digital pulse-shape discrimination approach based on the Charge Comparison Method (CCM) was used to distinguish different radiation types (α-, β particles, γ rays), while simultaneously exciting a composite scintillator. Obtaining separate projections of the PSD parameter (count number vs. PSD value) for the α, β, and γ events, and their gross counts are crucial in further dose estimation for different radiation types in Boron (^{10}B) Capture Nuclear Therapy (BNCT). Our findings in [1, 2] were differences in the light pulse shapes for α, β and γ rays, and the most recent investigations using the PSD approach [3] confirmed good α-γ discrimination in the studied composites scintillators (see 2D heatmaps of PSD parameters vs. pulse height in Fig. 2 [3]). In the PSD measurement, the composite scintillator was optically coupled to an Hamamatsu R6231-100 PMT whose anode pulses were collected and digitized using an eight-channel CAEN DT5730 digitizer board (2-Vpp dynamic range, 14-bit resolution, 500 MHz sampling rate). CAEN board features firmware programmable PSD capabilities for distinguishing different radiation types using field programmable gate arrays (FPGA). Using the CCM, two different integrals of the input signal are compared, and the PSD value is calculated as $(Q_{long\_gate}-Q_{short\_gate})/Q_{long\_gate}$, see Fig. 3. The PSD performance of composite materials was tested with ^{60}Co+^{241}Am (GAGG:Ce SC), ^{137}Cs+^{241}Am (TbAG:Ce SCF/GAGG:Ce SC), and ^{51}Cr+ ^{241}Am (TbAG:Ce,Mg SCF/GAGG:Ce SC). The β-γ and β-α PSD performance tests using ^{14}C and $^{90}Sr/^{90}Y$ β-emitters are ongoing.

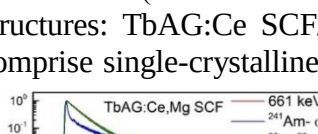

Fig. 3 Illustration of the PSD approach to α/β/γ discrimination.

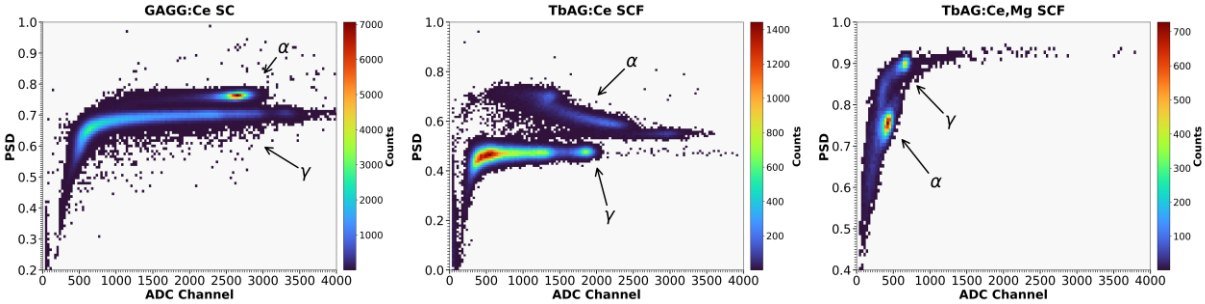

Fig. 2 2D heatmaps of PSD capability of GAGG:Ce SC, TbAG:Ce SCF/GAGG:Ce SC, and TbAG:Ce,Mg SCF/GAGG:Ce SC.

[1] S. Witkiewicz-Łukaszek, et al. Materials **2022**, 15, 1249. https://doi.org/10.3390/ma15031249
[2] A. Syntfeld-Każuch et al. "Characterization of novel composite scintillators based on the epitaxial structures of TbAG:Ce/GAGG:Ce and TbAG:Ce,Mg/GAGG:Ce in mixed radiation fields", presented at SCINT 2024, Milan, Italy.
[3] A. Syntfeld-Każuch et al. "Characterization of novel composite scintillators based on the epitaxial structures of TbAG:Ce/GAGG:Ce and TbAG:Ce,Mg/GAGG:Ce in mixed radiation fields", submitted to *Crystals*.