Composite scintillators based on the single crystalline films and crystals of garnet and perovskite compounds with extended capability for separation of β/γ radiation

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This work presents new results on the development of composite scintillators based on epitaxial structures of garnet and perovskite compounds. These structures are designed for the simultaneous detection of α, β, and γ radiation components in mixed radiation fluxes, with particular emphasis on effective β/γ separation, a feature that was difficult to achieve in previously developed multilayer composite scintillators [1].

Our previous studies demonstrated that an effective composite scintillator can be formed by combining a sufficiently thick, high-density, high-Z_{eff} substrate with a thin, low- or medium-density, low-Z_{eff} film that transmits highly penetrating radiation components [2]. However, in the case of composite scintillators with enhanced β/γ discrimination, this approach is usually less effective. Although α/β and α/γ separation has been successfully achieved for several composite scintillators based on different garnet compounds [1,2], efficient β/γ discrimination remains challenging due to the quite similar interaction mechanisms of β particles and γ quanta with scintillation materials in the final stages of the scintillation process.

This limitation requires consideration of a broader class of materials for the creation of composite scintillators (beyond garnets, perovskites, and orthosilicates), as well as different layer arrangements within the composite structure, including not only “light” films grown by LPE on “heavy” substrates but also the reverse configuration.

In this context, combinations of single-crystalline films (SCFs) $Tb_3Al_5O_{12}$ (TbAG) and crystals $Y_3Al_5O_{12}$ (YAG) garnets, with densities of 7.1 and 4.56 g/cm^3 and effective atomic numbers Z_{eff}≈53 and 29, respectively, are suitable host materials for new types of multilayer composite scintillators. Another type of composite scintillator is based on perovskite compounds and includes heavy Ce^{3+}-doped $Gd_{0.5}Lu_{0.5}AlO_3$ single-crystalline films (SCFs), grown by liquid phase epitaxy on relatively light Pr^{3+}-doped $YAlO_3$ (YAP) substrates. These materials also exhibit good scintillation potential due to their high densities of 6.5 and 5.35 g/cm^3, with Z_{eff} ≈ 47 and 33, respectively.

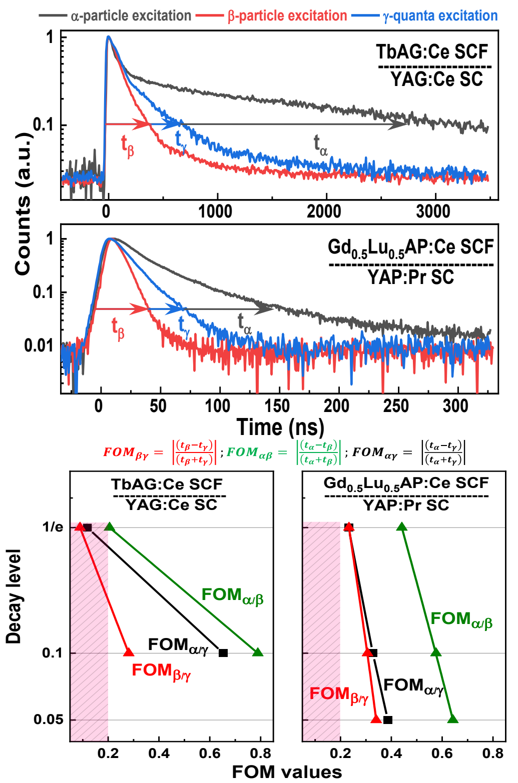

Fig.1 Decay kinetics in TbAG:Ce SCF/YAG:Ce SC, and GdLuAP:Ce SCF/YAG:Pr SC composite scintillators under excitation by α-(^{239}Pu) and β- (^{90}Sr) particles and γ-rays (^{137}Cs) excitations and theirs's FOMs.

The results presented in Fig. 1 show that the mentioned combinations of films and crystals exhibit very good ability to separate α/β and α/γ radiation, with a particularly pronounced capability for separating signals from β particles and γ quanta, both for garnet- and perovskite-based composites. Specifically, the figures of merit (FOMs), i.e., the quantitative differences between the signals, reached values of 0.3–0.35 for β/γ discrimination in both garnet- and perovskite-based composite scintillators. Therefore, it can be concluded that these epitaxial structures are well suited for the simultaneous registration of three types of ionizing radiation in mixed radiation fluxes.

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[2] S. Witkiewicz-Lukaszek, *et al*. Materials, *15*(3), **2022**, 1249.

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