Garnet-Based Composite Scintillators for Radiation Dosimetry in BNCT Applications

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The aim of this work is to develop multilayer composite scintillators capable of detecting the dose of various components of mixed radiation fluxes arising during Boron (^{10}B) Capture Nuclear Therapy (BNCT). Such scintillators are needed for accurately measuring the absorbed dose from various secondary radiations, including α-particles, ^{7}Li ions, and γ-rays, which is essential for both dosimetric-fantom laboratory studies and optimization of BNCT treatment conditions.

Recently [1], we showed that such composite scintillators can be fabricated in the form of multilayer structures consisting of two single-crystalline films (SCF) of materials, deposited on single crystal (SC) substrates using the liquid-phase epitaxy method. In these structures, the upper and middle SCF layers, with thicknesses in the ranges of 2–5 μm and 8–12 μm, respectively, are dedicated to the registration of short-range α-particles and ^{7}Li ions, whereas the single-crystalline (SC) substrates serve for the detection of highly penetrating γ-rays, forming a sequentially deposited multilayer detector architecture. The thin-film and bulk components of the structure are fabricated from efficient scintillator materials exhibiting distinct emission spectra and/or decay kinetics, achieved through controlled doping with different ions and /or modification of the host crystal composition.

The geometry of BNCT detection experiments also requires the application of so-called *fiber-optic detectors (FODs)*, in which the scintillation signal is transmitted to a selected type of photodetector via a long optical fiber. However, a key question in our detector design is the choice of appropriate methods for registering scintillation signals from different parts of the composite scintillators in proportion to the radiation doses from particles and γ quanta in BNCT. This discrimination can be achieved by exploiting differences in (i) pulse-height spectra (PHS); (ii) scintillation decay kinetics, and/or (iii) radio-luminescence (RL) spectra of the film and bulk crystal components of the composite scintillators (Fig.1). The PHS-based approach is highly sensitive but requires amplitude analysis, whereas decay-kinetics-based discrimination requires time-discrimination techniques. The third approach, based on RL spectral separation, is particularly attractive for FOD, and requires the use of a highly sensitive luminescence spectrometer.

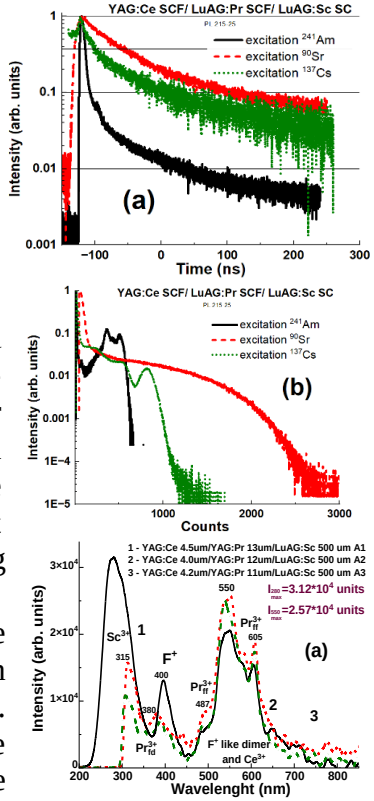

Fig.1. Different approaches for simultaneous measuring various radiation types using YAG:Ce SCF/LuAG:Pr SCF/LuAG:Sc SC composite scintillator: decay kinetic (a)and PHS (b) under excitation by α- (^{241}Am) and β- (^{90}Sr) particles, and γ quanta (^{137}Cs); and (c) RL spectra of composite under γ-ray excitation from a ^{192}Ir source (392 keV) at a dose of 2 Gy.

In this work, we produced and tested several groups of scintillation materials based on Ce^{3+}-, Pr^{3+}-, and Sc^{3+}-doped "light" $Y_3Al_5O_{12}$ (YAG) and "heavy" $Lu_3Al_5O_{12}$ (LuAG) garnets. The possibility of recording various types of radiation was demonstrated using: the differences in the scintillation decay kinetics (a) and PHS (b) of composite detectors under excitation by ^{241}Am (α), ^{90}Sr (β) and ^{137}Cs (γ) sources; the difference in the RL spectra of films and crystal scintillators under excitation by γ-rays of ^{192}Ir (392 keV) source (Fig.1c). The results were comparatively analyzed to identify the most promising material compositions for BNCT-related applications under laboratory conditions.

1. V. Gorbenko, T. Zorenko, S. Witkiewicz-Łukaszek, et all. *Appl. Radiation @ Isotopes*, **220**, 111726 (2025).

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