Radiation-induced modifications of luminescent properties of YAG:Ce, LuAG:Ce and TbAG:Ce single-crystalline films under 24.5 MeV ^{14}N Ion Irradiation

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Single-crystalline films (SCFs) of Ce^{3+}-doped $Y_3Al_5O_{12}$ (YAG:Ce), $Lu_3Al_5O_{12}$ (LuAG:Ce), and $Tb_3Al_5O_{12}$ (TbAG:Ce) garnets, are promising scintillator screens for microtomography due to their high X-ray absorption efficiency, high light yield (LY), and low phosphorescence [1,2]. However, their radiation resistance remains insufficiently understood. In bulk garnets, radiation tolerance is strongly affected by structural defects, particularly antisite defects (ADs) and oxygen vacancies formed during high-temperature growth. In contrast, SCFs grown by liquid-phase epitaxy at lower temperatures exhibit near-stoichiometric composition and significantly reduced intrinsic defect concentrations, making them suitable for studying intrinsic radiation effects [3, 4].

This work investigates absorption and luminescent properties of YAG:Ce, LuAG:Ce, and TbAG:Ce SCFs irradiated with 24.5 MeV ^{14}N ions at fluences of 10^{11}–10^{14} ions/cm^2 using the DC-60 accelerator (Astana). The irradiated samples were compared with as-grown films. Measurements included absorption, photoluminescence (PL), scintillation LY, and decay kinetics at room temperature, as well as synchrotron radiation (SR) studies (3.7–12.5 eV) at 300 K and 8 K (Superlumi station, PETRA III, DESY).

At fluences of 10^{11}–10^{13} ions/cm^2, measurable changes in luminescence and Ce^{3+} emission intensity occur mainly in LuAG:Ce and TbAG:Ce, while YAG:Ce exhibits higher radiation tolerance. In LuAG:Ce and TbAG:Ce, radiation-induced defects are attributed primarily to interstitial–vacancy pairs rather than antisite defects. This is supported by unchanged band-gap energies, stable excitonic luminescence and positions excitation band corresponding to excitons bound with Ce (BSE(Ce), preserved Ce^{3+} local environments (ESR), and absence of antisite-related UV emission bands.

The strongest effects are observed in TbAG:Ce, where shifts of the Ce^{3+} emission band and BSE(Ce) peaks indicate increased crystal-field strength and reduced local symmetry. These changes are attributed to irradiation-induced lattice strain, likely associated with oxygen-related interstitial defects. Thus, nitrogen irradiation predominantly induces local lattice distortions rather than cation disorder, with TbAG:Ce being most sensitive.

At the highest fluence (10^{14} ions/cm^2), all SCFs exhibit significant optical degradation, including reduced scintillation LY, enhanced excitation above the band gap, and altered PL and scintillation decay kinetics. These changes indicate the formation of competing radiative and nonradiative recombination channels involving the host lattice, Ce^{3+} ions, and defect-related centers.

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