SCINTILLATION RESPONSE OF Ce^{3+} doped GLGAG MULTICOMPONENT GARNET FILMS UNDER ELECTRON EXCITATION

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Highlights

Scintillation properties of Ce doped epitaxial garnet films
Tunnelling processes in multicomponent Gd, Ga - substituted LuAG:Ce garnets

Abstract

Ce^{3+} doped aluminium garnets, YAG:Ce, LuAG:Ce, are prospective scintillation materials for detection of gamma rays or high energy particles. Thin single crystalline films have potential application in high resolution screens for electron or X-ray detection [1]. The light yield of these garnet materials is, however, degraded by inevitable structural defects which result in trap states and appearance of slow light (delayed components) in scintillation decays. Recently, a new concept of multicomponent aluminium garnets has been proposed with partial substitution of Gd and Ga for (Y,Lu) and Al ions, respectively, where detrimental effect of shallow traps is significantly reduced [2].

In this work we studied the scintillation and luminescence properties of Ce^{3+}-doped multicomponent $(GdLu)_3(AlGa)_5O_{12}$:Ce (GLGAG:Ce) garnets. The single crystalline films with thickness of 10 - 30 μm were grown by liquid phase epitaxy from $BaO\text{-}B_2O_3\text{-}BaF_2$ flux onto YAG substrates. The cathodoluminescence (CL) and photoluminescence (PL) properties were measured at room temperature. The CL decays were studied under excitation by nanosecond electron beam pulse of 10 keV and with pulse duration of 50 ns. The CL decay experiments, measured with high dynamical resolution and in a broad time scale, give insight into the mechanism of delayed recombination in this material.

The experiments and analyses point to rather complex behaviour of garnet samples: the fit of the decays provides two components – an exponential term with the decay time ~56 ns and a power-law dependence of the intensity $\propto t^{-p}$, where p is close to 1 and t is time, Fig.1. The exponential decay originates from the prompt electron-hole recombination at Ce^{3+}, while the power-law function can be explained as tunnelling-driven energy transfer process [3], where electrons tunnel from shallow traps towards $5d_1(Ce^{3+})$ state where subsequently recombine. This tunnelling results in undesirable slow light in the scintillation response. In the multicomponent Gd,Ga- substituted garnets relative contribution of the power-law component to the overall intensity decreases compared to LuAG:Ce system and the dominant scintillation decay is due to prompt recombination of electrons and holes at the Ce^{3+} emission centres. These observations suggest that the shallow traps, responsible for the tunnel recombination, are significantly reduced in Gd, Ga substituted garnets and support the model in [4]: the combined effect of Gd, Ga substitution reduces the bandgap and the shallow trap states become buried into the conduction band.

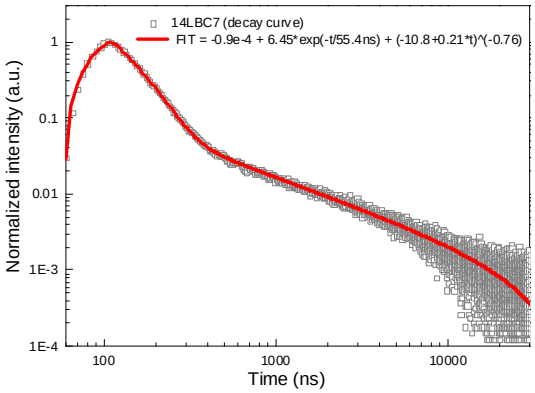

Fig. 1. Scintillation decay of GLGAG:Ce under 50 ns e-beam excitation. The solid line is convolution of instrumental response (not shown) to excitation pulse with the decay function consisting of one-exponential and a power-law terms, $I=a + b.e^{-t/\tau} + (c+d.t)^{-p}$.

References

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