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Scintillation parameters improvement of LuAG:Ce epitaxial films by Mg co-doping

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LuAG:Ce ($Lu_3Al_5O_{12}$:Ce) garnet scintillator is a scintillator of decent light yield and energy resolution, excellent chemical stability, very good mechanical properties, and fast scintillation decay. However, the LuAG:Ce response is negatively affected by traps, mainly related to Lu_{Al} antisite defects produced at high temperatures. Traps are responsible for very high intensity of slow scintillation response component and energy losses during the migration phase, therefore light yield decrease.

During the last decade, several approaches have been adopted to overcome the negative effects of traps. So-called band-gap engineering is based on targeted band positioning achieved by optimization of host matrix composition, resulting in trap inactivation. Alternatively, methods of growth at lower temperatures could be used to avoid emergence of antisite defects, e.g. liquid phase epitaxy or methods of ceramic scintillators production. Finally, co-dopants are applied as well, especially divalent Mg and Ca in case of LuAG:Ce.

Mg co-doping turned out to be particularly successful for LuAG:Ce [1,2] and YAG:Ce ($Y_3Al_5O_{12}$:Ce) [3]. Several researchers have reported increase of light yield, energy resolution improvement, and slow scintillation component intensity and afterglow reduction. Divalent ions presence changes Ce^{3+} ions to Ce^{4+} ions. It is widely accepted that Ce^{4+} center competes for electron with traps much more effectively than Ce^{3+} centers, which must at first capture a hole to be able to capture an electron. Therefore, less electrons are trapped in materials containing Ce^{4+} centers.

In this study, liquid phase epitaxy is for the first time combined with Mg co-doping of LuAG:Ce. 7 LuAG:Ce,Mg epitaxial films were prepared (Mg concentration: 0, 100, 300, 800, 1500, 1500, 3000 ppm). Light yield (LY) and photoelectron yield (PhY), respectively, exhibit strong dependence on Mg concentration. Using 1 µs amplifier shaping time, it reaches maximum for Mg concentration 800 Mg, 395 phels/MeV, i.e. 17 % higher than PhY of undoped sample. Decrease of slow scintillation component intensity with increasing Mg concentration is strongly evidenced by PhY(10 µs)/PhY(0,5 µs) ratio (monotonous decrease from 178 % down to 103 %), scintillation decay curves, and afterglow values. Results of the study are consistent with theory and previous results obtained on different LuAG:Ce,Mg systems (bulk crystals, ceramics).

References:

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