Materials for Ultra Fast PET Scintillators

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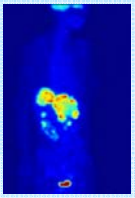
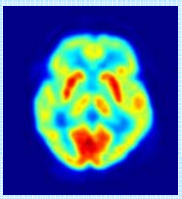
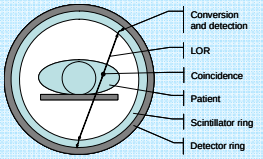
Background

The aim of the work was research on inorganic luminescent materials useful as radiation converter in Positron Emission Tomography (PET) machines. The research on new scintillator materials allows improving the performance, increasing safety and decreasing the cost of PET scanners. [1]

Host lattices were chosen from the group of already existing Ce^{3+} doped garnets scintillators. As innovation, Pr^{3+} fast ultraviolet (UV) emitting rare-earth ion was introduced as activator, doped into the structure in various of concentrations.







PET is a medical imaging technique that allows generating a three-dimensional, cross-sectional image of human body.

Before medical investigation starts, a patient is injected with a radioactive material, so called PET tracer. It cumulates in organs and tumours according to the specific metabolism.

PET tracers emit positrons, which rapidly annihilate with electrons in the body tissue. Each annihilation event produces two gamma rays, which are recorded by the detector system and subsequently translated into a 3D-image.

LuAG:Pr

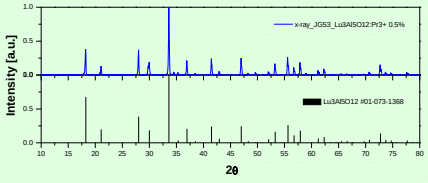


Fig. 1 X-ray patterns for LuAG:Pr^{3+} (0.5%) calcinated at 1700°C.

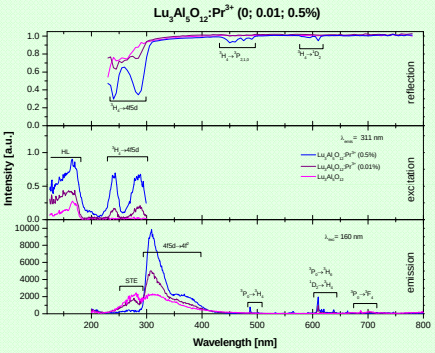


Fig. 4 LuAG:Pr (0, 0.01, 0.5%) reflection, emission, excitation spectra.

LuAGG:Pr

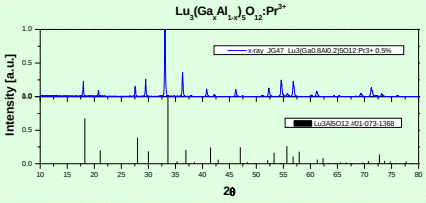


Fig. 2 X-ray patterns for LuAGG:Pr^{3+} (0.5%) calcinated at 1700°C.

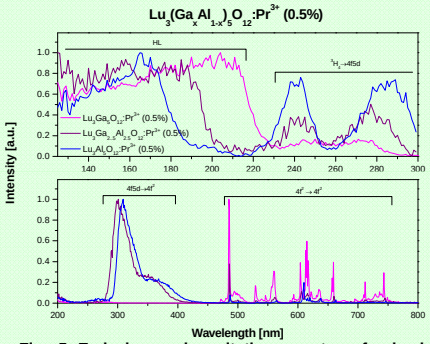


Fig. 5 Emission and excitation spectra of mixed crystals $Lu_3(Ga_xAl_{1-x})_5O_{12}:Pr^{3+}$ (0.5%).

LuGG:Pr

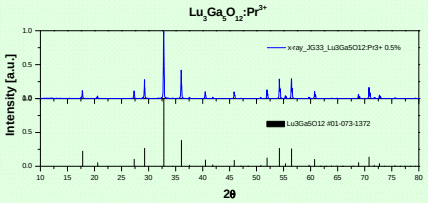


Fig. 3 X-ray patterns for LuGG:Pr^{3+} (0.5%) calcinated at 1500°C.

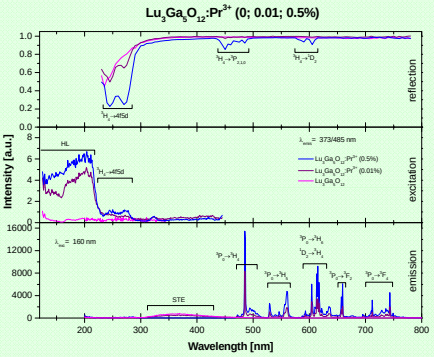


Fig. 6 LuGG:Pr (0, 0.01, 0.5%) reflection, emission, excitation spectra.

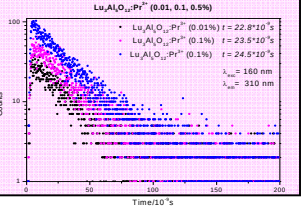
Experimental part

Doped samples were synthesized by usual solid-state technique. Initially starting materials as: Lu_2O_3, Al_2O_3, Ga_2O_3 and Pr_6O_{11} were weight in and milled with ethanol in the ball mill. The prepared mixtures were dried and calcinated afterwards for 5 hours.

The x-ray measurement was applied to ensure that obtained materials are phase pure. Recorded pattern shows (Fig. 3) that the crystallinity of the LGG structure, calcinated at 1500°C, does not depend of the present of the dopant. For LuAG and LuAGG that was not the case. Firing at 1500°C resulted with inhomogeneous powders. Therefore the calcinations at 1700°C were performed to obtain the pure phase samples as presented in Fig 1 and 2.

The samples obtained belong to cubic crystal system and are described by the Ia-3d (230) space group.

Emission, excitation and reflection measurements were performed for all samples. Pr-doped LuAG compositions which show 5d - 4f transitions were selected for further decay time measurements. For those samples short decay time, viz. $\tau_{1/e}$ ~ 23 ns was recorded.



References

[1] Korzhik, M., A. Fedorov, et al. (2007). "Development of scintillation materials for PET scanners." Nuclear Instruments and Methods in Physics Research A 571: 122–125.

[2] Nikl, M., J. Pejchal, et al. (2006). "Antisite defect-free $Lu_3(Ga_xAl_{1-x})O_{12}$:Pr scintillator." Applied Physics Letters 88: 141916.

Interpretation

Spectroscopic measurements of LuAG, LuAGG and LuGG samples doped with Pr^{3+} were observed to be different for various amount of dopant, where signal increases with increasing contribution of dopant.

The most interesting region of the emission spectra is between 220 nm and 400 nm where: intensive band of self-trapped exciton emission is observed for undoped sample, which may be instrumental in the energy flow and fast, 4f5d - $4f^2$ transition of Pr^{3+}, useful for PET applications, can be monitored.

Emission spectra of LuGG:Pr^{3+} doped samples do not show any 5d – 4f emission. Very strong and intensive parity forbidden 4f - 4f emission peaks are located between 470 nm and 750 nm therefore this composition cannot be applied in PET scanners.

It can be noticed that admixture of Ga^{3+} ions results in a high – energy shift of the 4f-5d absorption band, reflecting a decrease in the crystal field strength. The host lattice excitation band is shifted to lower energy for the samples with increasing amount of Ga^{3+} content. This is due to the increase of covalent bonding between the Ga^{3+} and O^{2-} ions in the lattice. A similar phenomenon is observed for YGG and YAG samples. [2]

Conclusions

As a result, applications of the examined Pr-doped LuAG composition in PET scanners may contribute to reducing the patients exposure to radioactivity. Further potential advantages are: Improved resolution of the image due to high light yield, faster response time, absence of afterglow and a high stopping power by the high density.