Development of Lithium-metaphosphate glass scintillator for thermal neutron

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1. Introduction

The scintillation method is widely used for detection of various kinds of ionizing radiation. Thermal neutron can be detected using the reaction $^{6}Li(n,\alpha)T$ and $^{10}B(n,\alpha)^{7}Li$. One advantage of lithium is the high amount of energy released in the reaction Moreover, this reaction is particularly suitable since no γ-rays are produced. [1]

These days, SiO_2-based glass scintillators with Li_2O are produced and sold with various ^{6}Li content [2]. Glass materials represent an interesting alternative to single crystal s in the field of solid-state scintillation detectors. Fabrication of the glass scintillator is easier than that of crystal, but there are some difficulties in the fabrication; it must be fabricated at a complicated composition [3] and it entails high costs. Relatively cheap liquid and plastic scintillator are unsuitable for detection of slow neutron because of low concentration of the converting nuclei. The Ce^{3+} decay time is short because the radiative transition from $5d^{1}4f^{0}$ to $4f^{1}5d^{0}$ is dipole allowed. Therefore cerium is widely used as luminescent ion in scintillator.

With respect to these criteria, the present work was aimed at investigation of glasses based on lithium metaphosphate with 0.5~1.5w t% cerium as an activator.

2. Methods and Results

2.1 Experimental setup and samples

The analysed samples are five sets of Ce^{3+} activated glasses, based on lithium metaphosphate matrix. The fabrication conditions are listed in Table 1. The mixture of quantitative reagent powders was melted in glass carbon crucible in an electric furnace. After being held for 90 min at 950℃ in an atmosphere of Ar plus sugar in the furnace, the melt was poured into a duralumin ring on glass carbon plate. The aim of adding sugar was reducing atmosphere preventing the formation Ce^{4+} in the glass. The glasses prepared in such an atmosphere are colorless. During 10-15 minutes, the glass was allowed to cool to room temperature. The glass samples for further studies were disc-shaped , 25 mm in diameter and 5 mm in thickness. Then annealed at 290℃ for 1 h, with subsequent grinding and polishing.

The scintillation properties were studied using Cf-252 neutron source with polyethylene moderator. Light signals from the scintillators came to the R669 PMT (Hamamatsu), and after it to an amplifying measuring circuit that included the AMP/TSCA amplifier (2015A, Canberra) and the Multi-channel analyzer (ULS1202, ULS). The ground power and H.V. power were supported by Model 2100 and 3102D(Canberra), separately.

Table 1. Fabrication conditions of $LiPO_3$ glass scintillators

Scintillator ($LiPO_3$:Ce^{3+})	Activator	Fraction of activator	Reduction condition
No.1		0.5 wt.%	
No.2		0.75 wt.%	
No.3	$CeCl_3$	1.0 wt.%	Atmosphere of Ar gas Sugar
No.4		1.25 wt.%	
No.5		1.5 wt.%	

a. Fraction of sugar : 1.0 wt.% of total weight for initial mixture

* Heating temp. : 950℃, Heating time : 90 min

2.2 Gamma-ray sensitivity

A good thermal neutron detector should have a low gamma-ray sensitivity; gamma-rays are always emitted by the neutron sources or the environment. The measured pulse height spectra for ^{60}Co gamma-ray source is shown in Fig. 1. Gamma sensitivity of ^{60}Co was background level when used 15mm thick lead shield

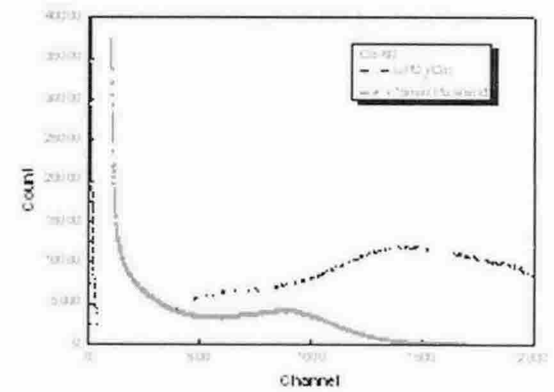

Figure 1. Pulse height spectra of $LiPO_3$:Ce^{3+} using 15mm thick lead shield for gamma-ray

Scintillator	Density [g/cm3]	Refractive index	Emission Max.[nm]	Hygroscopic	Energy Resolution	Decay time [ns]	Scintillation Yield [photon/neutron]
$LiPO_3:Ce^{3+}$	2.672	1.45~1.5	417	slightly	6.7%	615 ± 10	4,233
$LiI:Eu^{2+}$	4.08	1.96	470	Very	12.9%	1200	5,100

Table 2. Comparison of the characteristics of the most commonly used thermal neutron scintillation materials

2.3 Energy resolution and light output

To determinate the energy resolution and light output of $LiPO_3:Ce^{3+}$ scintillator, a pulse height distribution with a ^{272}Cf neutron source with polyethylene moderator was measured. The measured pulse height spectra for cf-252 neutron source is shown in Fig. 2. The energy resolution of $LiPO_3:Ce^{3+}$ scintillator doped with 0.5wt%, 1.0wt% and 1.5wt% were 7.7%, 6.7% and 8.7% for Cf-252 neutron source, respectively.

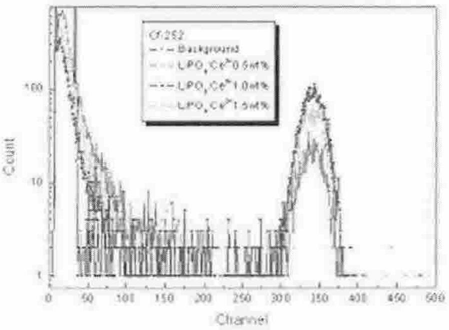

Figure 2. Pulse height spectra of $LiPO_3$:Ce3+ scintillator to Cf-252 neutron

The relative light output of $LiPO_3:Ce^{3+}$ scintillator was 83% (4,233 Photon/neutron) as compared with $LiI:Eu^{2+}$ scintillator.

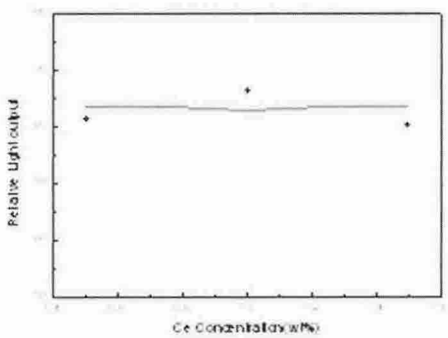

Figure 3. Relative of light output of $LiPO_3:Ce^{3+}$ as compared with $LiI:Eu^{2+}$

2.4 decay time

The decay time of $LiPO_3:Ce^{3+}$ scintillator was performed by means of the single-photon method[4]. An uncoated $LiPO_3:Ce^{3+}$ was optically coupled to the R669 PMT. The time distribution of the light pulse from $LiPO_3:Ce^{3+}$ came to an oscilloscope(Tektronix TDS 360). And we measured the light pulse using trigger(Fig. 4). The decay time constant of 615 ± 10 ns were measured using summed average function of oscilloscope.

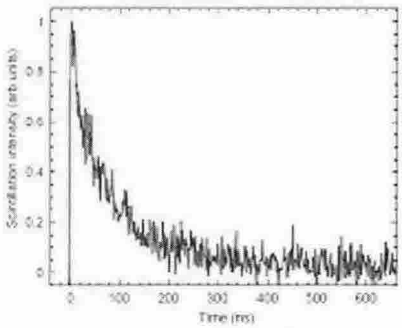

Figure 4. Light pulse shape of $LiPO_3:Ce^{3+}$ using the single-photon method.

3. Conclusion

$LiPO_3$ glass scintillators doped with 0.5, 0.75, 1.0, 1.25 and 1.5wt% cerium as an activator were prepared for the purpose of developing new scintillator for neutron detection. In table 2, Main characteristics of $LiPO_3:Ce^{3+}$ glass scintillator and $LiI:Eu^{2+}$ scintillator are compared. The data obtained show a possibility of using glass scintillator $LiPO_3:Ce^{3+}$ for the detection of neutron.

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