Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Properties analysis of lithium borate glass scintillator for neutron detection

Jin-Young Chung, Jung-Ryul Kim, Jin-Hyung Bai, Suk-Ho Choi*, Joo-ho Whang
Department of Nuclear Engineering, KyungHee University, Kiheung, Youngin, Kyunggi, Korea, 449-701
*Physics, KyungHee University, Kiheung, Youngin, Kyunggi, Korea, 449-701**
jinyoung@khu.ac.kr

1. Introduction

Nonlinear optics crystals are vital fundamental materials in optoelectronic technology, and also important for other fields, such as information, energy resource, medical application, etc. Lithium borate system has attracted considerable attention because this system contains many important nonlinear optics crystals, such as $2Li_2O–3B_2O_3$, $L_2O–B_2O_3$, $Li_2O–2B_2O_3$ (LB_2), $Li_2O–3B_2O_3$ (LB_3), etc[1][2][3][4].

This study fabricated a Li_2O-B_2O_3 glass scintillator with TMO (transition metal oxide) activators. The crystal structure of the fabricated Li_2O-B_2O_3 glass scintillator was confirmed, and experiments were conducted to study the absorption curve by density of the added activators, photorefractive effect, band-gap energy, emission spectrum and elemental composition. Also, the purpose of this study is to develop a glass scintillator with improved performance by improving on it through continued researches and experiments.

2. Materials and Methods

In this study TMOs (Transition metal oxides), i.e. Al_2O_3, MnO_2, NiO, Fe_2O_3, TiO_2 and V_2O_5 were added as activators to the main materials, Li_2CO_3 and H_3BO_3. As for the best heating conditions, repeated experiments set the melting temperature at 950℃, and melting time at 90 minutes.

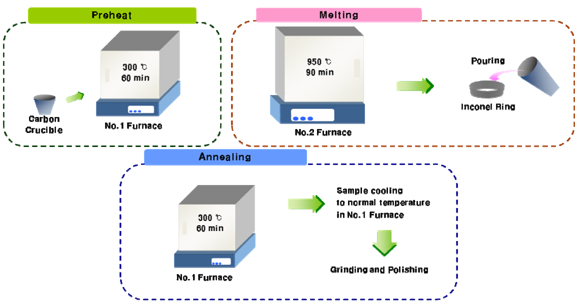

Figure 1. Preparing procedures of glass scintillator

Spectroscopic ellipsometry (V-VASE) was used to measure the transmittance and band-gap energy of the fabricated scintillator, and a spectrophotometer (HITACH U3000) was used to measure the absorption curve. 325nm He-Cd laser light was used to measure the photoluminescence of the scintillator at normal temperature. A lens was used to concentrated the emitted light, and 1m monochromator and GaAs photomultiplier were used to analyze the spectrum. To reduce the noise of the measured signals, the standard 'Lock-in measurement method' was used, and the frequency speed of the Chopper was 300ms. The diameter of the laser beam was approximately 0.3 mm, and the intensity of light was about 20 mW.

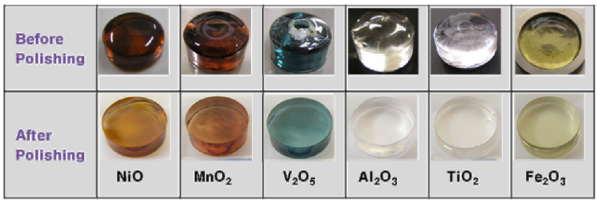

Figure 2. Prepared glass scintillator specimen

As for the ESCA operating conditions for analysis of the element composition of the Li_2O-B_2O_3 glass scintillator, a vacuum of 5×10^{-8} torr (with x-ray on, flood gun off) was created, and corrected with the C 1s (284.5 eV) value. Monochromatic Al-*K* (15 kV, 100W, 400 micrometer) as an X-ray source was used, and the elements in the samples were simply identified with the pass energy at 50 eV, and the step size at 1.0 eV for the wide scan. To obtain detailed information about certain elements on this basis, an appropriate analysis area was selected and a narrow scan was performed. Here, for the narrow scan, the pass energy was 20 eV, and the step size was 0.1 eV. Thermo VG's analysis program called Advantage was used for analysis.

3. Results

The XRD analysis of the Li_2O-B_2O_3 glass scintillator fabricated in this study, and the X-ray analysis of crystallization of the samples confirmed that they were amorphous substances. The result suggests that each element is formed independently and does not have any crystal structure. The densities of Li_2O-B_2O_3 glass were systematically measured by Archimedes principle[5]. The density was 2.0~2.3 g/cm^3, and the photorefractive effect of the Li_2O-B_2O_3 glass scintillator measured by Spectroscopic ellipsometry (SE) was 1.48~1.55. The wavelength of the absorption spectrum of the Li_2O-B_2O_3 glass scintillator measured by UV-VIS Spectrophotometry ranged between 300 and 350nm, and the central wavelengths of the emission spectrum pumped to the absorption edge were Al_2O_3 434nm and 592nm, MnO_2 425nm and 602nm, NiO 434nm, Fe_2O_3 434nm and 760nm, TiO_2 518nm, and V_2O_5 555nm respectively. The materials with the best emission intensity were Al_2O_3 and MnO_2, and the material with the best emission intensity near 400nm of interest to the authors was Al_2O_3, whose emission wavelength was 434nm.

Table 1. Measured densities and Band-gap energy

No.	Scintillator	Density [g/cm^3]	Band-gap energy[eV]
1	Li_2O-B_2O_3-Al_2O_3	2.132	5.62
2	Li_2O-B_2O_3-V_2O_5	2.038	3.434
3	Li_2O-B_2O_3-TiO_2	2.153	4.93
4	Li_2O-B_2O_3-MnO_2	2.335	4.07
5	Li_2O-B_2O_3-Fe_2O_3	2.277	4.094
6	Li_2O-B_2O_3-NiO	2.070	3.37

Table 2. Compositions of glass scintillator according to additives

No.	Scintillator	Element ratio			
		O	Li	B	TMO
1	Li_2O-B_2O_3-Al_2O_3	49.79	10.98	38.8	0.44
2	Li_2O-B_2O_3-V_2O_5	51.43	12.15	36.38	0.04
3	Li_2O-B_2O_3-TiO_2	51.51	10.08	38.27	0.14
4	Li_2O-B_2O_3-MnO_2	52.12	9.92	37.85	0.12
5	Li_2O-B_2O_3-Fe_2O_3	49.16	13.17	37.67	-
6	Li_2O-B_2O_3-NiO	51.03	10.92	38.05	-

The measurements of the element composition of the Li_2O-B_2O_3 glass scintillator based on ESCA showed that Li and B, main materials, accounted for about 10% and 40% respectively, O about 50%, and the remainder was analyzed quantitatively by means of TMO.

4. Discussions

In this study a Li_2O-B_2O_3 glass scintillator with TMO (transition metal oxide) added as an activator was fabricated to develop a scintillation detector for detection of neutrons. The analysis of the characteristics of this glass scintillator and its comparison with commercial glass scintillators with lithium revealed that part of the data satisfied the requirements for a scintillator for detection of neutrons, and its performance was good enough to be used as a neutron detector. However, compared to commercial glass scintillators, its physical properties and overall performance were not sufficient. In addition, additional R&D must be dome in terms of the composition of a scintillation detector and a neutron detection system and applicability. Accordingly, if the performance of two glass scintillators were compared, and continued R&D were conducted to analyze the physical properties of Li_2O-B_2O_3 glass scintillators and improve their performance, it would be possible to develop a glass scintillator which is more economical than glass scintillators containing lithium, and performs as well. The fabrication technology and data on basic characteristics can be utilized for fabrication of several inorganic scintillators with outstanding performance. The characteristics of the Li_2O-B_2O_3 glass scintillator analyzed in this study can be used for detection of neutrons.

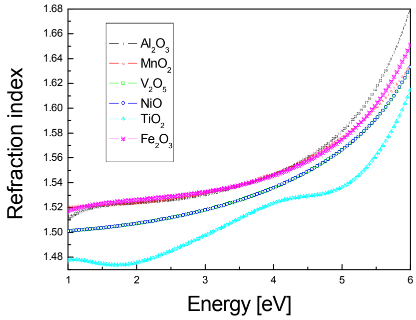

Figure 3. Photorefractive indices

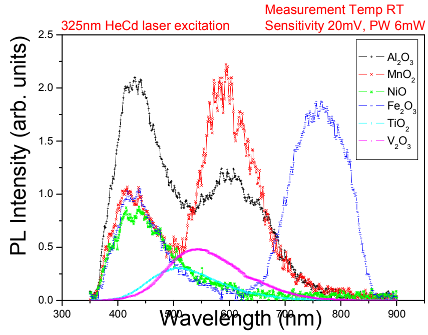

Figure 4. Emission spectra and wavelengths

5. Future Works

Further researches on light efficiencies of the glass scintillator prepared in this study for neutron irradiation should be performed. In addition, by changing compositions for glass scintillator showing good performance, it will also be carried out to calculate compositional ratios for neutron glass scintillators and to prepare ones with best performance.

Acknowledgement

This work was supported by the SRC/ERC program of MOST/KOSEF, and by MOCIE through EIRC program.

REFERENCES

[1] I.W.DONALD, B.L.METCALFE, D.J.BRADLEY, M.J.C.HILL, J.L.McGRATH, A.D.BYE, "The preparation and properties of some lithium borate based glasses," Journal of Materials Science 29,pp 6379-6396, 1994.

[2] N.A.El-Alaily, R.M.Mohamed, "Effect of irradiation on some optical properties and density of lithium borate glass," Materials Science and Engineering B98, pp 193-203, 2003.

[3] S.Y.Marzouk, N.A Elalaily, F.M Ezz-Eldin, W.M.Abd-Allah, "Optical absorption of gamma-irradiated lithium-borate glasses dopes with different transition metal oxides," Physica B 382, pp 340-351, 2006.

[4] AST, "Lithium glass(neutron & gamma characteristics)," Applied Scintillation Technologies, Phosphor data sheet 41b, 2000.

[5] XM. Shi, Q. Wang, ┌, C.X. Li, X.J. Niu, F.P. Wang, K.Q. Lu, "Densities of Li2O–B2O3 melts," Journal of Crystal Growth 290, pp 637–641, 2006.