Journal of Ceramic Processing Research. Vol. 15, No. 3, pp. 146~148 (2014)

J O U R N A L O F
Ceramic Processing Research

Themoluminescence properties of Tl doped LiF single crystal

Hyunja Jeong[a], Sunghwan Kim[b], Kyuho Jeoung[b], Sajid Khan[c], H.J. Kim[c], Jongkyu Cheon[d] and Uk-won Nam[e,]*

[a]Daegu Health College, Daegu 702-722, Korea
[b]College of Health Science, Cheongju University, Cheongju 360-763, Korea
[c]Department of Physics, Kyungpook National University, Daegu 702-701, Korea
[d]Department of Radiology, Sorabal College, Gyungju 780-711, Korea
[e]Korea Astronomy and Space Science Institute, Daejeon 305-348, Korea

In this study, we present luminescence properties of a new developed Tl-doped LiF thermoluminescence single crystal using by Czochralski method, such as emission spectrum, decay time, thermoluminescence fading etc. The shape of glow curve the crystal was strongly dependent on LET of radiations more than that of TLD-100 (LiF : Mg,Ti). We studied the induced TL trap parameters of the crystal irradiated by X-ray and alpha.

Key words: Czochalski, HTR method, LiF, LET, Thermolumineascence.

Introduction

Space is very dangerous place for astronauts because of high level of radiations. They are irradiated by the radiations such as high energy protons, electrons and charged particles, during accomplishment of space mission and staying on the earth orbits. To prevent their health from radiation damage, their radiation safety and accurate personal dosimetry are very important. So, many radiation monitoring researches are carried out on International Space Station (ISS) and air aircrafts [1-4]. Space radiations consists of directly ionizing radiation in the form of high-energy charged particles such as trapped radiation, galactic cosmic radiation (GCR), and solar particle events (SPE) [5, 6]. The measurement of linear energy transfer (LET) of high energy charged particles is important for estimation of the crew's equivalent dose [7]. Thermoluminescence dosimeters (TLDs) and plastic nuclear track detectors were frequently used for personal radiation dosimeter as passive radiation detector [8-11]. TLD-100 (LiF : Mg,Ti, Harshaw Chemical Co.) is most commonly used material for personal space dosimetry. In general, the shape and height of TL glow peak of TLD are changed according to dose and LET of induced radiations [12]. In high temperature peak (HTR) method [13], we can measure the absorbed dose and LET of induced radiation because the shape and peak ratio between main TL glow peak and high temperature TL glow peak are dependent on the LET of the radiation.

*Corresponding author:
Tel : +82-43-229-7992
Fax: +82-43-229-8969
E-mail: kimsh@cju.ac.kr

In this paper, we developed a new Tl doped LiF material by using Czocharlski method and characterized the TL properties of the material for high LET radiation dosimetry. We expect that the material is more useful for high LET radiation monitoring because the shape of glow curve of LiF : Tl is more strongly dependent on the LET.

Material and Methods

LiF : Tl single crystal was grown by the Czochralski technique in an induction heated platinum crucible with the diameter of 30 mm. The growing process was performed in the Ar-gas atmosphere with the pulling rate of 3.0 mm/h and the rotation rate of 25 rpm. To reduce crystal cracks, a low thermal gradient was set up in the furnace. The chemicals used for the crystal growth were the LiF (99.95% purity, Sigma-Aldrich) and the TlF (99.99+% purity, Sigma-Aldrich). The transparent and uniform LiF : Tl single crystals of 20 mm in diameter and 30 mm in height were grown as shown in Fig. 1. The samples of LiF:Tl single crystals with the dimension of $1 \times 1 \times 3$ mm^3 were cut from the grown crystals and polished using mixed Al_2O_3 powder (grain size of 0.02 μm) in mineral oil with a polishing cloth (Buehler, No.40-7218) for measurement of TL properties. The X-ray excited luminescence spectrum of LiF : Tl crystal is recorded at room temperature. The X-ray irradiation is carried out with an X-ray tube (DRGEM Co.) using a tungsten anode at 100 kV and 1 mA. The X-ray excited luminescence spectrum of the sample crystal is measured with a spectrometer (QE65000 fiber optic spectrometer) made by Ocean Optics. The samples were irradiated by diagnostic X-ray and 5.5 MeV α particles of ^{241}Am α-source. After irradiation, the TL properties of

Fig. 1. The grown Tl doped LiF single crystals.

the material were measured by using TL reader (Neo TL system, Neosis Co.)

Results and Discussion

Fig. 2 shows the emission spectrum of the LiF:Tl irradiated by X-rays. The emission spectrum exhibits a broad band between 300 nm and 550 nm, peaking at 329 nm and 385 nm. The two excited states of Tl^+ ion are the $^1P_1{}^0$ and $^3P_1{}^0$ states. These emissions are due to the $^1P_1{}^0 \leftrightarrow {}^1S_0$ and $^3P_1{}^0 \leftrightarrow {}^1S_0$ transitions of the Tl^+ ion [14]. The wavelength of emission is well matching with the quantum efficiency of general photo-multiplier tube.

Fig. 3 shows the TL glow curves of the LiF : Tl single crystal irradiated by X-rays and alpha particles. The curves are composed of 3 peaks as shown in Fig. 3. The main TL peaks (peak 2 and 3) are located at 418 K and 505 K. However, when the material is irradiated by high LET radiation, the height of peak 2 is decreased and the height of peak 3 is increased, relatively. And then, the HTR is also increased. From this fact, we can confirm that the peaks are strongly dependent on the LET of the radiation.

The TL peaks were analyzed by using TL/OSL glow curve analyzer (ver. 1.1.0) from Korea Atomic Energy Research Institute (KAERI) [15]. When the material is irradiated by X-rays, the activation energy and frequency factor of main peak are 1.37 eV and $1.32 \times 10^{16} s^{-1}$, respectively. However, when the material is irradiated by alpha particles, the activation energy and frequency factor of main peak are 1.16 eV and $9.0 \times 10^{10} s^{-1}$, respectively. The HTR is defined in equation (1) [16]. In Fig. 3, the determined HTR value of LiF : Tl for a particles is about 3.4.

$$\left(\frac{Height\ of\ Peak_{II}}{Height\ of\ Peak_{III}}\right)_{X-ray} \left(\frac{Height\ of\ Peak_{III}}{Height\ of\ Peak_{II}}\right)_{alpha} \qquad (1)$$

The most important characteristic of TLD is the TL dose response. The intensity of TL should be linear to the irradiated dose. Fig. 4 shows the relation between irradiation dose and TL intensity. In the dosage range of 50 mR ~ 5,000 mR, the TL intensity of the material is linear to irradiated dose.

Fig. 5 presents the fading characteristic of LiF : Tl at room temperature. The fading of TL signal is influenced by temperature and humidity. As shown in Fig. 5, the fading rate of the material during first 1 hour is about 10%. However, the fading rate is decreased with the increase of elapsed time. The calibration process of TL fading is necessary to use for personal dosimetry because the fading is relatively larger than commercial TLD-100.

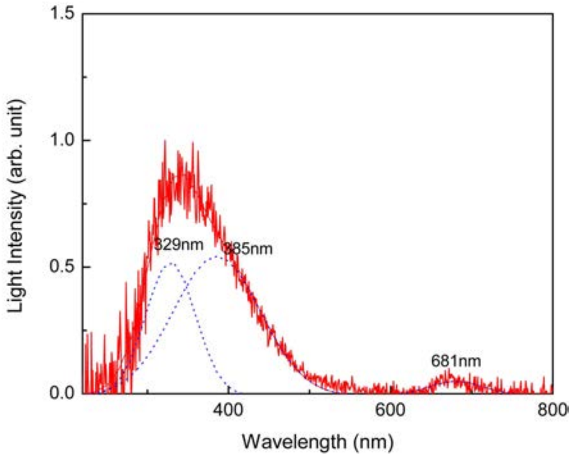
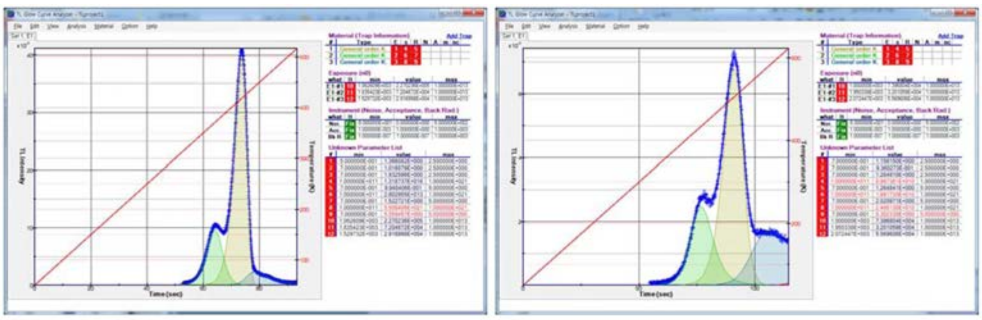


Fig. 2. Emission Spectrum of LiF : Tl excited by X-ray.



(a) Irradiated by X-ray (b) Irradiated by alpha particles

Fig. 3. Analysis of TL glow curves of LiF : Tl.

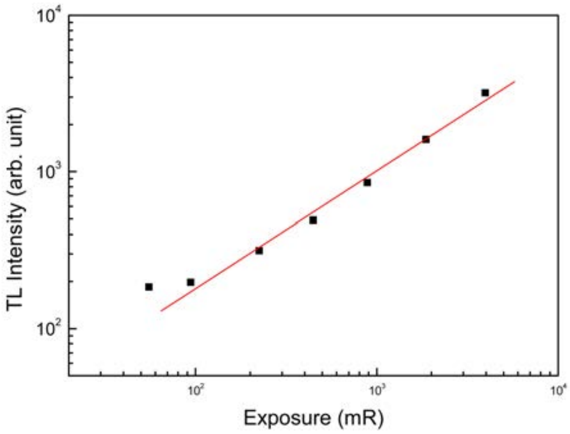


Fig. 4. Dose dependence of LiF : Tl irradiated by X-rays.

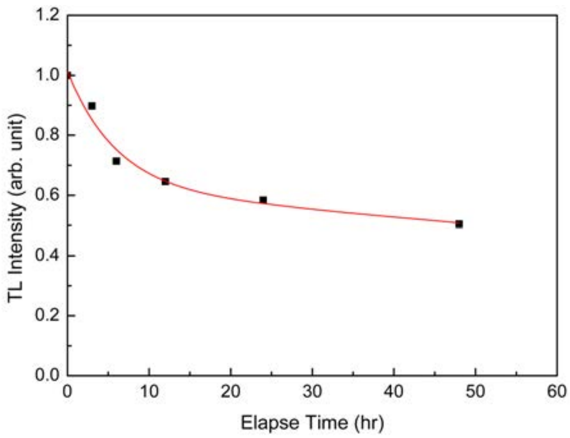


Fig. 5. TL fading characteristic of LiF (Tl) at the room temperature.

Conclusions

We developed a new Tl doped LiF crystal for radiation dosimetry by using Czochalski method. The range of emission spectrum of the material is well matched with PMT and the shape of glow curve is strongly dependent on LET of the radiations. The TL intensity of the material is linear to the irradiated dose in the range of 50 mR ~ 5,000 mR and fade to 60% after 50 hr at room temperature. We think that the material is useful for high LET radiation monitoring. So, we suggest it as a candidate material for radiation dosimetry in radiation mixed field.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (NRF-2011-0021004).

References

1. H. Tawara, T. Doke, T. Hayashi, J. Kikuchi, A. Kyan, S. Nagaoka, T. Nakano, S. Takahashi, K. Terasawa, and E. Yoshihiraet, Rad. Meas. 35 (2002) 119-126.
2. J.W. Norbury, Adv. in Space Res. 47 (2011) 611-621.
3. G. Martin, S. Gerdung, M. Raabe, and E. Arend, Rad. Prot. Dos. 99 (2002) 379-380.
4. U. Schneider and L. Walsh, Adv. in Space Res. 44 (2009) 202-209.
5. F. Spurn, Rad. Phys. Chem. 61 (2001) 301-307.
6. A.B. Akopova, Rad. Meas. 39 (2005) 225-228.
7. International Commission on Radiation Units and Measurements, Report 85, 11 (1) (2011).
8. Frantisek Spurny, Rad. Meas. 38 (2004) 407-412.
9. M. Hajek, T. Berger, R. Bergmann, N. Vana, Y. Uchihori, N. Yasuda, and H. Kitamura, Rad. Meas. 43 (2008) 1135-1139.
10. D. Zhou, E. Semones, M. Weyland, and E.R. Benton, Rad. Meas. 42 (2007) 1499-1506.
11. N. Vana, W. Schöner, M. Fugger, and Y. Akatov, Rad. Prot. Dos. 66 (1996) 145-152.
12. Y.S. Horowitz, L. Oster, H. Datz, and M. Margaliotet, Rad. Meas. 43 (2008) 203-207.
13. A. Triolo, M. Brai, A. Bartolotta, and M. Marrale, Nucl. Instr. Meth., 560 (2006) 413-417.
14. P.D. Johnson and F.E. Williams, J. Chem. Phys. 20 (1952) 124-133.
15. K.S. Chung, H.S. Choe, J.I. Lee, and J.L. Kim, Rad. Meas. 46 (2011) 1598-1601.
16. T. Berger, G. Reitz, M. Hajek, and N. Vana, Adv. in Space Res. 37 (2006) 1716-1721.