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Dependence of the Glow Curve Structure for a New KLT-300(LiF:Mg,Cu,Na,Si) TL Detector on the Dopants Concentration

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A new TL detector KLT-300 (KAERI LiF TL detector doped with Mg, Cu, Na, Si) for personal and medical monitoring purposes was recently developed at KAERI (Korea Atomic Energy Research Institute). The main parameters in preparation of the detector were the concentration of the dopants. In this research, the investigation of the glow curve structure for KLT-300 was performed with respect to the various concentrations of the Mg (0-0.25 mol%), Cu (0-0.07 mol%), Na and Si (0-1.5 mol%) dopants. With increasing the Cu concentration, the intensity of the main peak was very rapidly intensified and reached the maximum at a concentration of 0.05 mol% and then the high temperature peak was very rapidly reduced. The dependence of the main peak intensity on the Mg concentration exhibits a sharp maximum at 0.2 mol%. The intensity of the high temperature peak tends to slightly rise with an increasing Mg concentration. With increasing Na and Si concentrations, the main peak intensity was slightly intensified and reached a maximum at 0.9 mol%.

KEYWORDS : Thermoluminescence, TLD, LiF, KLT, glow curve structure.

I. Introduction

LiF:Mg,Cu,Na,Si TL material, doped with four different activators, have been studied for a practical pellet-type TL detector at Korea Atomic Energy Research Institute (KAERI)[1) 2)] since it was introduced by Doh *et al.*[3)]. A new sintered pellet-type LiF:Mg,Cu,Na,Si TL detector which has a high sensitivity and good reusability, named KLT-300(KAERI LiF:Mg,Cu,Na,Si TL detector), was recently developed by the variation of dopant concentrations and the parameters for the preparing procedure at KAERI.[4)]

It is a basic requirement that TL material has a suitable glow curve structure for applying it to thermoluminescence dosimetry. A glow curve structure and luminescent efficiency are mainly dependent on impurities, doped in a host material, because a trap distribution is determined by the impurities of the host material. Therefore, the investigation of the dependence of the glow curve structure on the concentration of the dopants is a main area of study in developing a new TL material.

A prior study on the dependence of the glow curve structure on the concentration of dopants for LiF:Mg,Cu,Na,Si TL material was reported.[5)] However, the sample that was optimized in the previous study had some problems, poor reusability and a relatively low photon sensitivity compared with the LiF:Mg,Cu,P material (MCP-N, Poland).[6)] The sensitivity was about 50% of that of MCP-N. And, the optical transparency of the material was much lower because of its dark blue colour which was due to a high concentration of Cu. So, there is a need to reinvestigate the optimum conditions in the preparation of the LiF:Mg,Cu,Na,Si TL material.

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In this paper, the results of new investigations on the dependence of the glow curve structure for a LiF:Mg,Cu,Na,Si TL detector with dopants concentrations is reported.

II. Materials and Methods

1. Sample preparation

The sample preparation procedures were as follows. With the LiF powder, $MgSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_20$, and $Na_2O \cdot 2SiO_2 \cdot 9H_2O$ were mixed in distilled water by a magnetic stirrer. The mixture of LiF and dopants as above were dried and heated in an electric furnace at a temperature well below the melting point of LiF for 30min under a controlled nitrogen atmosphere for the activation process of the LiF crystals. After the activation, the LiF was quickly quenched to room temperature and then pulverized. The pulverized crystals were rinsed with a hydrochloric acid. The crystals of a grain size under 40～200 ㎛ were abstracted and fabricated to a pellet-type with a 4.5mm diameter and 0.8mm thickness by pressurizing with a mechanical press. To increase the mechanical stability of the pellet-type detector and to obtain the most preferable glow curve structure for a TLD, the pressed pellet was sintered in an electronic furnace at 830℃ under a controlled nitrogen atmosphere and cooled on a frozen aluminum plate. As a final step, the above cooled pellet was firstly annealed in an electronic furnace at 250℃.

The investigation of the glow curve structure of the LiF:Mg,Cu,Na,Si TL detector was performed with respect to the various concentrations of Mg (0-0.25 mol%), Cu (0-0.07 mol%), Na and Si (0-1.5 mol%) activators.

2. TL measurement

TL measurements were performed using a manual-type commercial TLD reader (System 310, Teledyne Brown Engineering) in the range between room temperature(RT) and 300℃ with a heating rate of 10℃/sec in a N_2 atmosphere after dose of 10 mGy with 137-Cs source at KAERI.

III. Results and Discussion

Fig. 1 and **Fig. 2** show the glow curves and the variations of the main peak intensity for different Mg concentrations with a fixed Cu concentration of 0.05 mol% and Na, Si concentration of 0.9 mol%, respectively. The dependence of the intensity of the main peak, which appeared at about 215 ℃, on the Mg concentration exhibits a sharp maximum at 0.2 mol%. The intensity of the high temperature peak, which appeared at about 250 ℃, tends to slightly rise with an increasing Mg concentration. The result agrees with Nam[5] except the position of the maximum TL intensity. In the previous paper[5], the Mg concentration which shows the maximum TL intensity was 0.6 mol%. On the other hand, the result agrees with Wang[7] and Bilski[8] for the LiF:Mg,Cu,P material, including the maximum position.

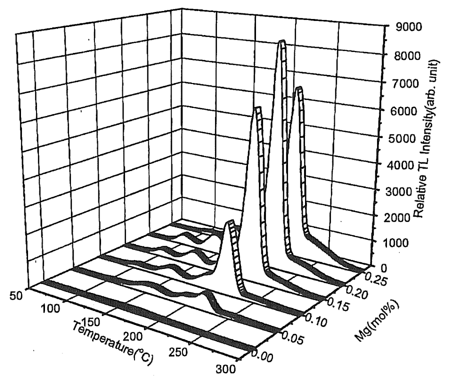

Fig. 1 Glow curves for different Mg concentrations. Cu: 0.05 mol%, Na,Si: 0.9 mol%.

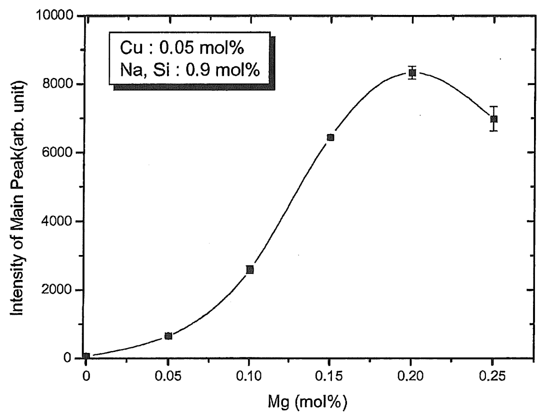

Fig. 2 Dependence of main peak intensity (peak height) on Mg concentration. Cu: 0.05 mol%, Na,Si: 0.9 mol%.

Fig. 3 and **Fig. 4** show the glow curves and the variations of the main peak intensity for different Cu concentrations with a fixed Mg concentration of 0.2 mol% and Na, Si concentrations of 0.9 mol%. The results reveal that Cu has a very strong influence not only on the main peak intensity but also on the glow curve structure in spite of a relatively very small amount of concentration variation. With an increasing Cu concentration, the intensity of the main peak was very rapidly intensified and the high temperature peak was very rapidly reduced. The maximum intensity appeared at 0.05 mol%. The trend of the glow curve structure with the variation of Cu concentration agrees with the previous study, but the Cu concentration which shows the maximum TL intensity is significantly different from the previous 0.8 mol%[5].

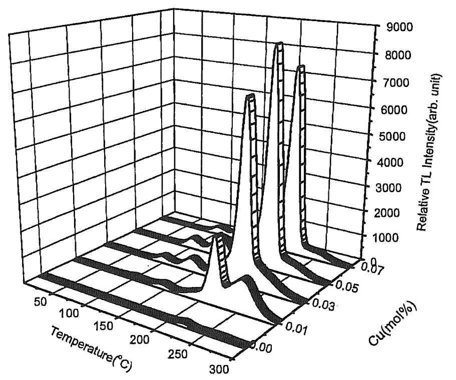

Fig. 3 Glow curves for different Cu concentrations. Mg: 0.2 mol%, Na,Si: 0.9 mol%.

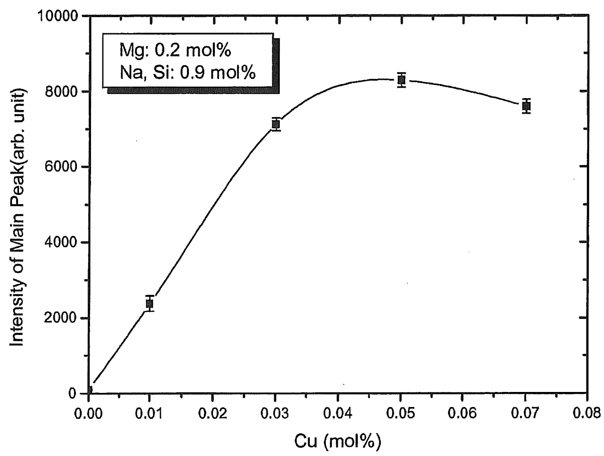

Fig. 4 Dependence of main peak intensity (peak height) on Cu concentration. Mg: 0.2 mol%, Na,Si: 0.9 mol%.

Fig. 5 and **Fig. 6** show the glow curves and the variations of the main peak intensity for different Na, Si concentrations with a fixed Mg concentration of 0.2 mol% and Cu concentration of 0.9 mol%. With an increasing Na and Si concentration, the main peak intensity was slightly intensified and had a maximum at 0.9 mol%.

As shown in **Fig. 5**, even in the case of a zero percentage of Na and Si, the TL intensity is about 30% that of the maximum, and the glow curve structure is nearly same with that of optimum condition. Though it was reported that the dependence of the TL intensity on P concentration is a step function for the LiF:Mg,Cu,P material[8], this pattern was not observed in this material.

Therefore, it seems that the Na and Si are not essential dopants in LiF:Mg,Cu,Na,Si.

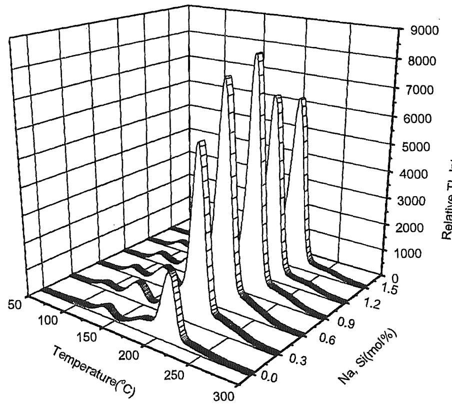

Fig. 5 Glow curves for different Na, Si concentrations. Mg: 0.2 mol%, Cu: 0.05 mol%.

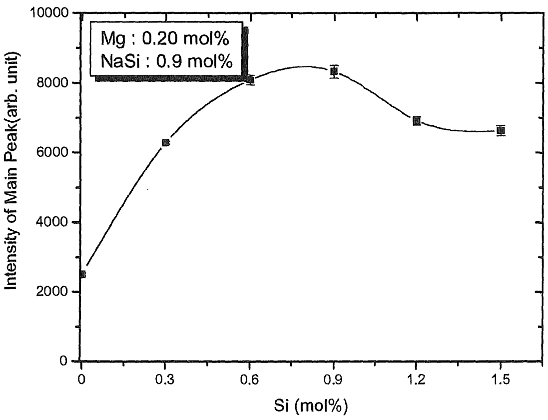

Fig. 6 Dependence of main peak intensity (peak height) on Na, Si concentration. Mg: 0.2 mol%, Cu: 0.05 mol%.

Through the above results, it is determined that the optimum concentration of dopants in the LiF:Mg,Cu,Na,Si TL material are Mg: 0.2mol%, Cu: 0.05mol%, Na and Si: 0.9mol%. It is a very significantly reduced amount of dopants compared to previous results[5].

Fig. 7 shows the optical microscope images of LiF:Mg,Cu,Na,Si TL powder with dopants concentrations of (a) Mg: 0.6mol%, Cu: 0.6mol%, Na and Si: 1.8mol% which were optimized in the previous report, (b) Mg: 0.2mol%, Cu: 0.05mol%, Na and Si: 0.9mol% which were optimized in this research. In the images (a), the transparent grains are LiF crystal and the blue parts are a mixture of Cu compounds. As shown in the image, it seems that the excess Cu dopant combined with other excess dopants and was agglutinated to the surface of LiF crystal. These Cu compound are not TL material but an obstacle to the emission of TL. In case of (b), the blue parts are not observed. It seems that most of the dopants diffused into the LiF crystal homogeneously.

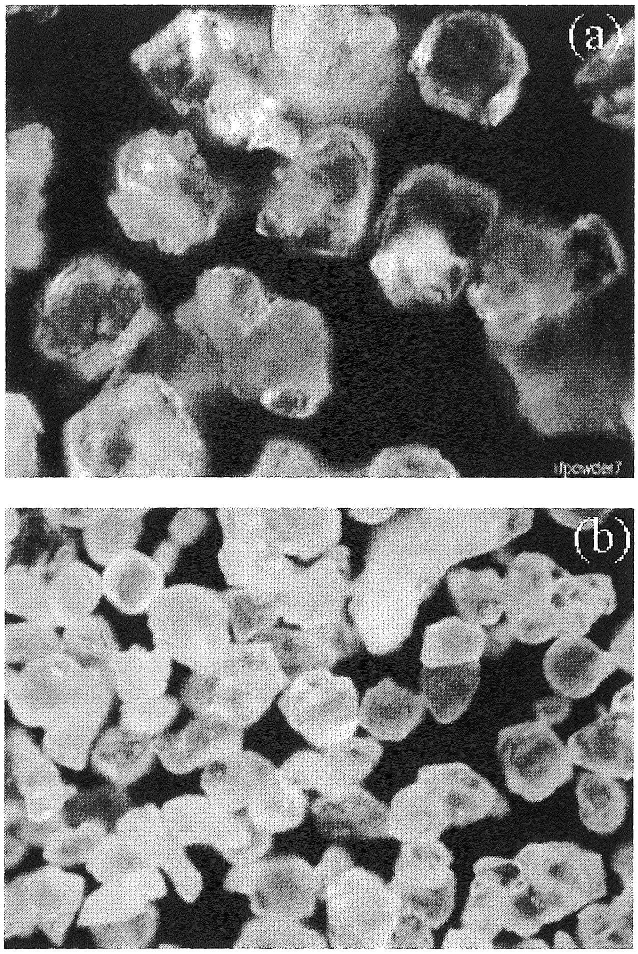

Fig. 7 The optical microscope images of LiF:Mg,Cu,Na,Si TL powder with dopants concentrations of (a) Mg: 0.6mol%, Cu: 0.8mol%, Na and Si: 1.8mol%, (b) Mg: 0.2mol%, Cu: 0.05mol%, Na and Si: 0.9mol%.

The total TL signal and glow curve structure of the newly optimized LiF:Mg,Cu,Na,Si TL detector were compared with the detector for Mg: 0.6mol%, Cu: 0.8mol%, Na and Si: 1.8mol%.

The comparison was carried out in the same manner and under the same experimental conditions and the same dimensions and weight for both detectors which have a 4.5mm diameter and 30mg weight. The measured typical glow curves of both TL detectors are represented in **Fig. 8**. It was found that the sensitivity(integration of total signal) is about 2 times higher than that for Mg: 0.6mol%, Cu: 0.8mol%, Na and Si: 1.8mol%.

IV. Conclusion

We have studied the dependence of the glow curve structure for the LiF:Mg,Cu,Na,Si TL detector with various concentrations of Mg (0-0.25 mol%), Cu (0-0.07 mol%), Na and Si (0-1.5 mol%) activators.

The results show that the optimum concentration of dopants in the LiF:Mg,Cu,Na,Si TL material are Mg: 0.2mol%, Cu: 0.05mol%, Na and Si: 0.9mol%. In the case of zero percentage of Mg and Cu, the TL signals are very weak(less than about 3% of the maximum). On the other hand, in the case of zero percentage of Na and Si, the TL signals are about 30% of the maximum. These results may suggest that Mg and Cu play main dopant roles, but Na and Si affect the TL emission indirectly.

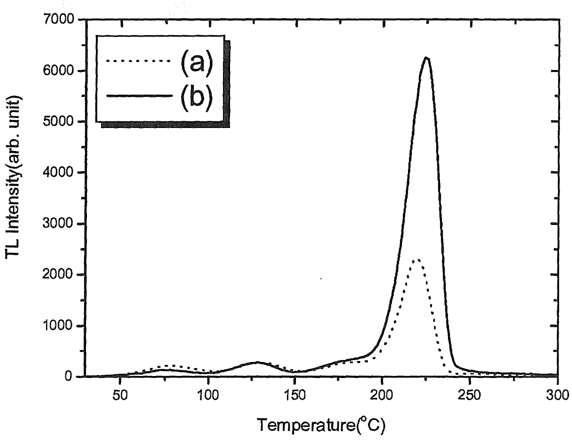

Fig. 8 Glow curves for dopants concentrations of (a) Mg: 0.6mol%, Cu: 0.8mol%, Na and Si: 1.8mol%, (b) Mg: 0.2mol%, Cu: 0.05mol%, Na and Si: 0.9mol%.

Acknowledgement

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References

1) Y. M. Nam, J. L. Kim, S. Y. Chang, et al., "The Study of Glow Curves for LiF:Mg, Cu, Na, Si Phosphor with Different Dopant Concentrations," Ungyong Mulli, 11, 578 (1998)
2) Y. M. Nam, J. L. Kim, S. Y. Chang, et al., "Fabrication of LiF:Mg, Cu, Na, Si Pellets by Sintering Process," Saemulli, 40, 189 (2000)
3) S. H. Doh, M. C. Chu, W. H. Chung, et al., "Preparation of LiF(Mg,Cu,Na,Si) Phosphor and Its Thermoluminescent Characteristics," Korean Appl. Phys., 2, 425 (1989)
4) J. I. Lee, J. L. Kim, J. S. Yang, et al., "Development of Highly Sensitive LiF:Mg,Cu,Na,Si TL Detector," AOCRP-1, 126, (2002)
5) Young-Mi Nam, Jang-Lyul Kim and Si-Young Chang, "Dependence of Glow Curve Structure on the Concentration of Dopants in LiF:Mg,Cu,Na,Si Phosphor," Radiat. Prot. Dosim., 84, 231 (1999)
6) M. Budzanowski, J.L. Kim, Y.M. Nam, et al., "Dosimetric properties of sintered LiF:Mg,Cu,Na,Si TL detectors," Radiat. Prot. Dosim., 33, 537 (2001)
7) S. Wang, "The Dependence of Thermoluminescence Response and Glow Curve Structure of LiF(Mg,Cu,P) TL Materials on Mg,Cu,P Dopants Concentrations," Radiat. Prot. Dosim. 25, 133 (1988)
8) P. Bilski, M. Budzanowski and P. Olko, "A Systematic Evaluation of the Dependence of Glow Curve Structure on the Concentration of Dopants in LiF:Mg,Cu,P," Radiat. Prot. Dosim. 65, 195 (1996)