Glow Curve Analysis of Post-irradiation Annealed TL Materials

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1. Introduction

A thermoluminescence dosimeter (TLD) is one of the tools for a radiation dose assessment with its characteristics that the amount of thermoluminescence from a TLD material is proportional to the absorbed radiation dose by a material.

TL glow curve is in compliance with several kinds of physical quantities of material. It is needed to analyze correctly to improve the accuracy of radiation dose assessment. Now we have several kinds of models to analyze TL glow curve. General Approximation Plus[1)] model, recently developed TL glow curve analysis model which can consider deep trap information. Both LiF:Mg,Cu,Si[2)] and LiF:Mg,Cu,P[3)] have similar TL intensity and glow curve structure. But the thermal stability of the LiF:Mg,Cu,Si is better than that of the LiF:Mg,Cu,P material. We used General Approximation Plus model for glow curve analysis of the post-irradiation annealed TL Materials to make a distinction between LiF:Mg,Cu,Si and LiF:Mg,Cu,P .

2. Methods and Results

2.1 TL Intensity of General Approximation Plus Model

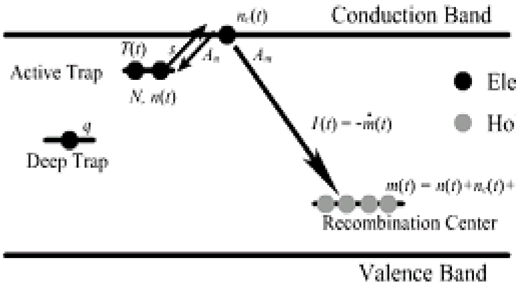

Fig. 1 A simple model of thermoluminescence

In the simple model of thermoluminescence model, same as Fig.1, TL equation is described by the following three equations[4)];

$$-\frac{dm}{dt} = A_m m n_c$$

$$-\frac{dn}{dt} = sne^{-\frac{E}{kT}} - A_n(N-n)n_c$$

$$\frac{dn_c}{dt} = \frac{dm}{dt} - \frac{dn}{dt} = sne^{-\frac{E}{kT}} - n_c[mA_m + (N-n)A_n]$$

The terms involved are: n is the concentration of the electrons in the traps, n_c is the concentration of the electrons in the conduction band, q is the concentration of the deep trap, m is the concentration of the holes in the recombination centers, N is the concentration of the available electron trap, A_m is the recombination transition coefficient for the electrons in the conduction band with holes in the recombination centers, A_n is the transition coefficient for the electrons in the conduction band becoming trapped, s is the frequency factor, k is the Boltzmann constant and E is the thermal activation energy.

With the following assumptions,

$$n_c << n+q\,,\ \left|\frac{dn_c}{dt}\right| << \left|\frac{dn}{dt}\right|,\ I = -\frac{dm}{dt} \approx -\frac{dn}{dt}\,,\ R \equiv \frac{A_n}{A_m}\,,$$

$$m = n + n_c + q\,,\ \alpha \equiv \frac{n_0}{n_0+q}\,,\ n_{c(initail)} \approx 0$$

The TL intensity can be expressed as

$$-\frac{dn}{dt} = \frac{sn(n+q)e^{-\frac{E}{kT}}}{(n+q)+R(N-n)}.$$

2.2 Variation of Glow Curves of LiF:Mg,Cu,Si with The Annealing Time

Fig. 2 shows the variation of the glow curves of LiF:Mg,Cu,Si annealed at 155℃ with the annealing time. TL intensity decreased and the peak positions shifted to the low temperature with the increasing annealing time.

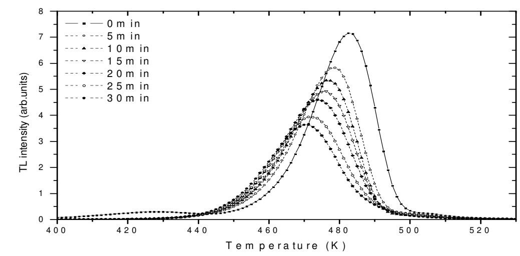

Fig. 2 TL glow curves of post-irradiation annealed LiF:Mg,Cu,Si TLDs.

2.3 Variation of Glow Curves of LiF:Mg,Cu,P with The Annealing Time

Fig.3 shows the variation of the glow curves of the LiF:Mg,Cu,P annealed at 155℃ with the annealing time, which were changed with the increasing annealing time. There does not seem to be big differences in the decreasing pattern in comparison with the case of LiF:Mg,Cu,Si.(Fig.2)

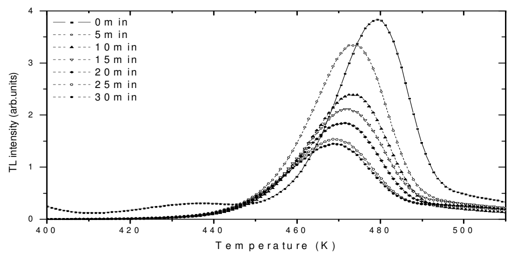

Fig. 3 TL glow curves of post-irradiation annealed LiF:Mg,Cu,P TLDs.

2.4 Example of Analyzed Glow Curve

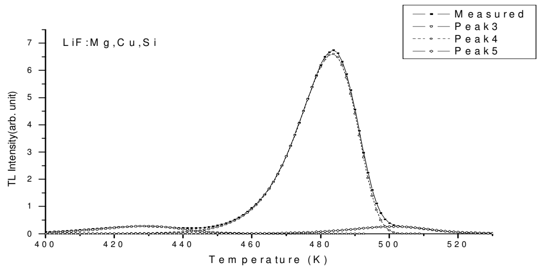

Fig. 4 Computerized glow curve deconvolution for the glow curve of LiF:Mg,Cu,Si

Fig. 4 shows an example of the analyzed glow curve of the LiF:Mg,Cu,Si. From the analyzing all the glow curves measured from the samples with the GAP model, the parameters such as the activation energies and α values of the glow curves were determined.

2.5 Variation of Analyzed Activation Energy for the Post-irradiation Annealed TLDs with the Annealing Time

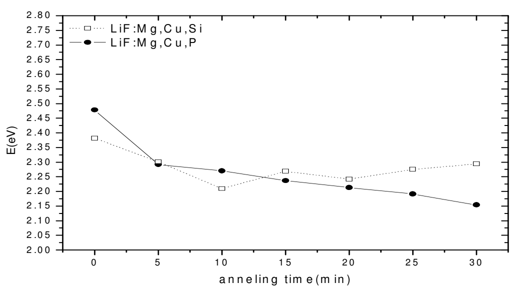

Fig. 5 Variation of activation energy for post-irradiation annealed TLDs with the annealing time

The variation of the activation energy for post-irradiation annealed TLDs with the annealing time is shown in Fig.5. The activation energy of LiF:Mg,Cu,Si was fluctuated between only 2.35 eV and 2.2 eV with a increasing annealing time, but for the LiF:Mg,Cu,P, the activation energy was decreased from 2.48 eV (no annealing) to 2.15 eV (30 min annealing). Therefore it seems that LiF:Mg,Cu,Si is more stable to the thermal annealing in comparison with LiF:Mg,Cu,P.

2.6 Variation of α Value for Post-irradiation Annealed TLDs with The Annealing Time

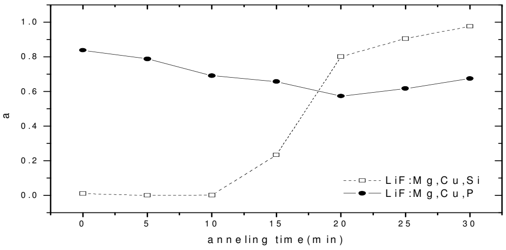

Fig. 6 Variation of the α value for the post-irradiation annealed TLDs with the annealing time

Fig. 6 shows the variation of the α value for the post-irradiation annealed TLDs with the annealing time. Even though the glow curve of both TLDs look similar, there were significant differences in the analyzed α values between LiF:Mg,Cu,Si and LiF:Mg,Cu,P. The α value of LiF:Mg,Cu,Si was increased from around 0.01 to 0.92 with the increasing annealing time. This means that the initial concentration of the electrons in the deep trap was decreased with increasing annealing time. These mean that even a deep trap could be influenced by thermal annealing which was only intended to remove the shallow trap, and the concentration of electron in the deep trap in LiF:Mg,Cu,Si is considerably high (at least 90 times of that of main dosimetric trap). On the other hand, the α value of LiF:Mg,Cu,P was not changed significantly with the increasing annealing time, which is different from the behavior of the α value of LiF:Mg,Cu,Si. It was analyzed that the α value of LiF:Mg,Cu,P was around 0.8, this means the concentration of electron in a deep trap was not so high (one fourth of that of main dosimetric trap).

3. Conclusions

In this study, the effects of a low-temperature thermal annealing on the activation energies of main dosimetric TL glow peaks and the behavior of deep traps in two similar TL materials (LiF:Mg,Cu,Si and LiF:Mg,Cu,P) by using a computerized glow curve deconvolution method based on the General Approximation Plus model, were evaluated.

The activation energy of the main glow peaks of LiF:Mg,Cu,P was decreased gradually from 2.48 eV (no annealing) to 2.15 eV, but that of LiF:Mg,Cu,Si was fluctuated within ± 3 %. From these results, it could be concluded that the thermal stability of the main glow peak of LiF:Mg,Cu,Si is better than that of the LiF:Mg,Cu,P material.

It was analyzed that the concentration of electrons in a deep trap in LiF:Mg,Cu,Si was extremely high in comparison with that in LiF:Mg,Cu,P. However, the concentration was decreased rapidly with the increasing annealing time.

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