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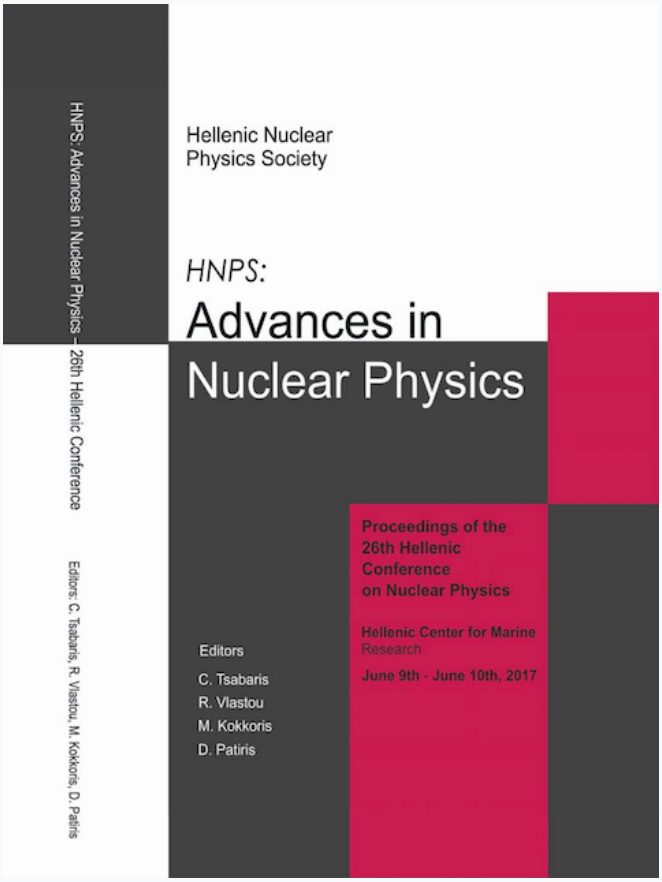

Beta ray sensitivity of LiF dosimeters as a function of radiation temperature

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Sensitivity of LiF:Mg+,Tl+ dosimeters as a function of radiation temperature

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Abstract It is widely known that Lithium Fluoride (LiF) is the most used thermoluminescence dosimetric material. For this particular reason, the study of this TLD is encouraged and new experimental data are presented. The present study focuses on the high temperature peaks and their β-ray sensitivity as a function of radiation temperature. The samples that were used are the well-known ^{6}LiF and ^{7}LiF. Three different experimental procedures were performed, namely Initial Rise, simultaneously heating followed by irradiation and Post radiation heating. The glow curves have been analyzed using the general order kinetic model. Furthermore, through the initial rise protocol it was deduced the activation energy of the high peaks for both case of ^{7}LiF and ^{6}LiF. Finally, the analysis of the integrated TL signal for the high temperature peaks, which were recorded from the last two protocols, led to several interesting conclusions.

Keywords LiF, TLD, activation energy, high temperature peaks, radiation temperature

INTRODUCTION

Lithium Fluoride (LiF) is well known as thermoluminescence dosimetric material (TLD). Due to its importance in dosimetric applications, the main dosimetric, which is usually referred as peak 5, in TLD is probably the most intensely studied peak in the history of thermoluminescence [1] [3]. However, special interest arises at the high temperature glow peaks, which are named as 6, 7 and 8 after their sequence on the recorded glow curve. Their thermal dependence was analyzed by Sadek et al. [2] and was deduced by Olko et al. [3]. Between the peaks 5 and 6 there is another peak named 5a and can be seen under some certain experimental circumstances. Kitis and Otto [4] showed that the 5a peak cannot be observed in the usual glow curve and thus it will not be elaborated in this study. The used samples are labeled with the laboratory names of TLD-600 (^{6}LiF) and TLD-700 (^{7}LiF) and are taken from the American Harshaw-TLD family. The data were analyzed by using the general order kinetic model for Thermoluminescence Deconvolution with the proposed excel sheet by Afouxenidis et al. [5].

The aims of the present work are the following:

i. Study of the β – ray sensitivity of LiF dosimeters as a function of radiation temperature.
ii. Further study of the high temperature glow peaks activation energies and kinetic parameters of the LiF dosimeters.

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iii. Comparison between the two different TLD types (^{6}LiF and ^{7}LiF).

EXPERIMENTAL PROTOCOLS

The samples used in this experiment were crystals of 3,2x3,2x0,15mm. TL measurements were carried out using a Harshaw-3500 TLD-Reader. The irradiations were applied through a ^{90}Sr/^{90}Y beta source, delivering a beta dose rate of 0,38 Gy/min. All measurements were performed in a nitrogen atmosphere with a low constant heating rate of 2^{o}C/s for both samples.

The first protocol that was performed is called Initial Rise:

- **Step 0:** Test dose (TD) of 0.38 Gy and TL measurement up to T=350°C for both samples.
- **Step 1:** Dose of 7.6 Gy and TL measurement up to T_{max}=180°C for TLD-700 and T_{max}= 170^{o}C for TLD-600.
- **Step 2:** TL measurement up to T_i .
- **Step 3:** Repeat step 2 for different T_i by a step of 5 ^{o}C.

Where T_i is varying from 185°C to 350°C for TLD-700 and from 175°C to 350°C for TLD-600.

The second protocol applied was named Simultaneous Irradiation with heating (Tir):

- **Step 0:** TD and TL measurement up to T_{max}= 350°C.
- **Step 1:** Dose of 1.9 Gy with simultaneously heating at T_i temperatures.
- **Step 2:** Record TL glow curve up to T_{max}= 350°C.
- **Step 3:** Repeat Steps 2-3 with T_i temperatures varying from 50^{o}C to 230°C with a step of 1°C.

The last experimental protocol, namely Post Radiation heating (Tpost):

- **Step 0:** TD and TL measurement up to T_{max}= 350°C.
- **Step 1:** Dose of 1.9 Gy and 5 minutes heating at T_i.
- **Step 2:** Record TL glow curve up to T_{max}= 350°C.
- **Step 3:** Repeat Steps 2- 4 with T_i temperatures varying from 50°C to 230°C with a step of 10°C.

RESULTS AND DISCUSSION

In the present work, for the Glow Curve Deconvolution process was used the General Order Kinetic model, and the analysis was after the following equation:

$$I(T) = s \cdot n_0 \cdot e^{\frac{-E}{kT}} \cdot \left[1 + \frac{s(b-1)}{\beta} \cdot \int_{T_0}^{T} e^{\frac{-E}{kT'}} dT'\right]^{\frac{b}{b-1}}$$

Where, **I:** TL intensity, **s:** frequency factor, $\mathbf{n_0}$**:** initial concentration of trapped electrons, **E(eV):** activation energy, **β(K/s):** heating rate, **K(eV/K):** Boltzmann constant, **b:** Kinetic order.

The Deconvolution was accomplished by using the solver sheet in excel as it is proposed by Afouxenidis et al. [5].

Figure 1 shows the glow curves of the TLD-600 dosimeters, while those of the TLD-700 dosimeter are not presented since they are identical to the presented glow curves of the TLD-600. This figure also illustrates the experimental name of each peak.

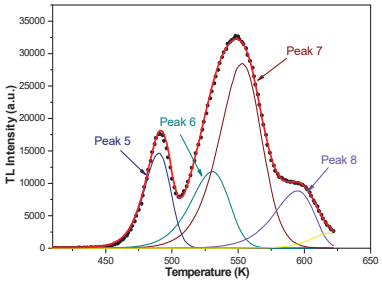

Fig. 1. Glow Curve Deconvolution with the General Order Kinetic model.

Figure 2 shows the results of the initial rise methods used for both dosimeters. There are actually presented the calculated activation energies as a function of the experimental temperature. These energies have a wide range which will be narrowed by the following procedures. For both samples there is a plateau exceeded from 1.7 to 2.1eV for temperatures from 240 to 330°C.

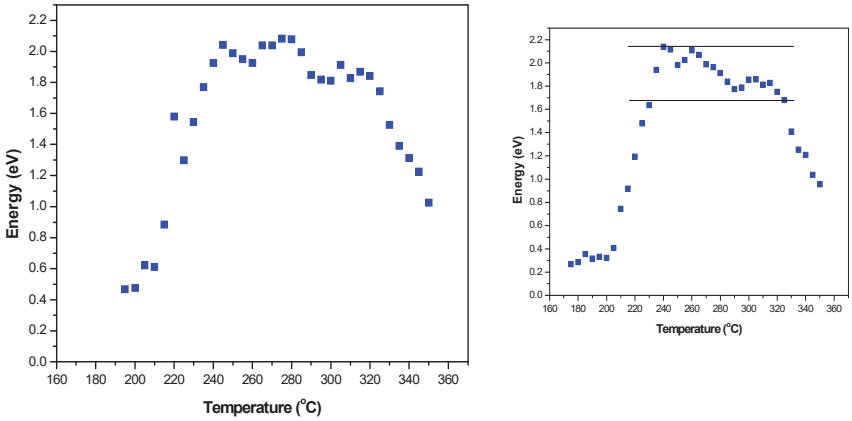

Fig. 2. Energies calculated from the Initial Rise method of high temperature TL peaks for TLD-700 (Left) and for TLD-600 (Right).

The following figures 3 and 4 show the difference in the normalized intensity between the two procedures of thermal treatment as a function of temperature. The peak 5 has similar behavior for both dosimeters. In the case of Post Radiation technique, the intensity is at the beginning almost stable, in contrast to the simultaneous protocol where a slight increase is observed.

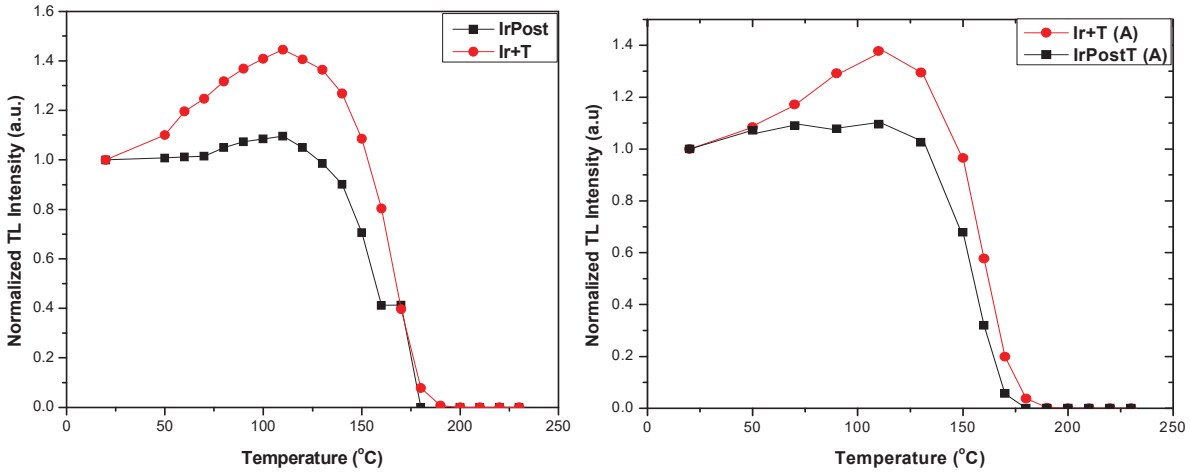

Fig. 3. TL sensitivity of peak 5 for the cases of the 2nd and 3rd protocol for TLD-700 (left) and TLD-600 (right).

It seems that a different pattern is recorded for the high temperature peaks. In the case of TLD-700, the normalized TL intensity increases for the second protocol by a magnitude of 5, while it is almost stable for the protocol with the Post Radiation. On the other hand, for the case of TLD-600 it seems that even the Post Radiation procedure has caused a little increase in the normalized TL intensity unlike the peaks of the TLD-700 dosimeter. This phenomenon where the different thermal procedures end up to a different result can be seen at Fig. 4.

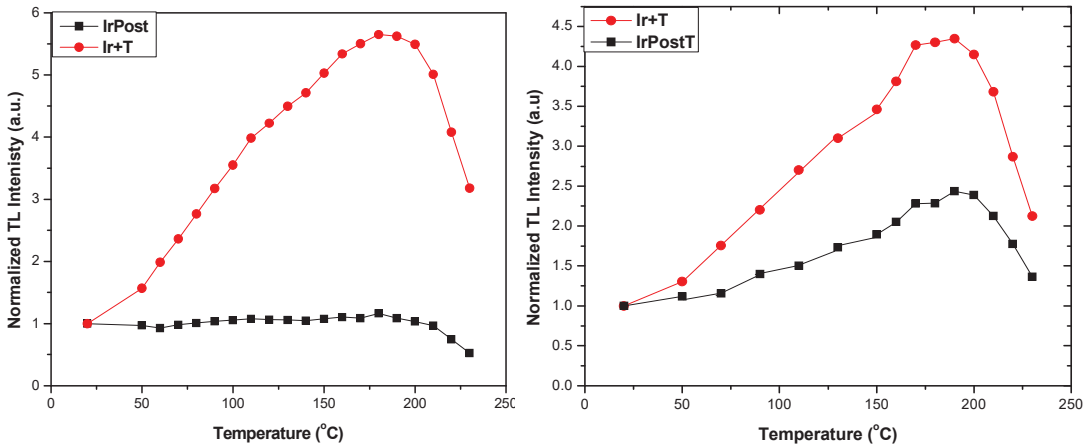

Fig. 4. Sensitivity of high temperature TL peaks for TLD-700 (left) and TLD-600 (right) for both protocols.

The following table summarizes the experimental results concerning the activation energies of the two samples for the peaks 5 to 8. Peaks 6 and 7 have different energies from those that were deduced by Sadek et al [2].

Ev	TLD-700	TLD-600
Peak 5	2.2928 ± 0.0109	2.2631 ± 0.0345
Peak 6	1.7824 ± 0.0213	1.7647 ± 0.0930
Peak 7	1.8670 ± 0.0323	1.9059 ± 0.1053
Peak 8	1.9917 ± 0.0336	2.009 ± 0.1062

Table 1. Estimated activation energies for TLD-700 and TLD-600 with their corresponding errors.

CONCLUSIONS

- For the case of TLD-700: The sensitivity of the glow peak 5 seems to increase between the two procedures by 36%, while the integrated TL signal of the high temperature peaks increases by a factor of 5.7. The high temperature activation energies range from 1.77 to 2.0781 eV.
- For the case of TLD-600: Once again the sensitivity of the glow peak 5 seems to increase but this time by 27%, while the integrated TL signal of the high temperature peaks increases by a factor of 2. The high temperature activation energies range from 1.6792 to 2.1382 eV.
- The high temperature peaks display an interesting behavior between the two samples. Thus, it is strongly recommended these peaks to be studied thoroughly before drawing a safe conclusion.

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