# Thermoluminescence Properties of Local Feldspar from Gattar Mountain Area

**W. E. Madcour[1], M. A. El-Kolaly[1] and S.Y. Afifi[2]**
[1]*Radiation Protection Department, Nuclear Research Center, Atomic Energy Authority, Egypt*
[2]*Nuclear Materials Authority ,Cairo, Egypt*

**Received: 1/1/2016** **Accepted: 28/2/2016**

## ABSTRACT

**The thermoluminescent properties of K-Feldspar from Gattar mountain area at Eastern Desert of Egypt show variation in intensity of characteristic glow curves with respect to exposure dose. The sensitivity of the sample under investigation is very low (with a clear fading portion) compared to that of high sensitivity TL dosimeters. The observed peak in the glow curve corresponds to the summation of five or more overlapping peaks. Such summation behavior of these approximately low temperature peaks increases the fading percentage in shallower traps. However, the fading of peaks in the deep traps indicates the existence of partial electron transfer in these overlapping peaks.**

***Keywords: Thermoluminescence, Feldspar, Glow Curve, Fading, Heating Rate.***

## INTRODUCTION

TL is the thermally stimulated emission of light that follows a previous absorption of radiation energy [(1)]. Glow curve of TL materials represents the variation of the output of the emitted light as a function of temperature [(1)]. Shape of the glow curves is one or more peaks of emitted light and some of them may overlap. The behaviors of thermoluminescence glow curves are intensively described by energy band model. The energy band model shows the electronic transitions of a TL material during irradiation and heating [(2)]. A simple TL model assumed two energy levels in the forbidden gap, one situated below the bottom of the conduction band and the other situated above the top of the valance band.

Feldspar as many minerals is known to be a naturally occurring TLD material [(3)]. The characteristic TL properties depend on the type and concentration of impurities in the feldspar sample (mainly rare earth elements). The location of the feldspar plays an important role in minerals formation and impurities concentration.

For general order kinetics, the maximum peak intensity ($I_m$) and peak temperature $T_m$ can be derived as [(4)];

$$I(T) = I_m (b)^{\frac{b}{b-1}} exp\left(\frac{E}{kT}.\frac{T-T_m}{T_m}\right)\left[(b-1)\left(1-\frac{2kT}{E}\right)\frac{T^2}{T_m^2}\ exp\left(\frac{E}{kT}.\frac{T-T_m}{T_m}\right)+Z_m\right]^{\frac{b}{b-1}} \quad (1)$$

Where $E$ is the trap depth or the activation energy, $K$ is the Boltzmann's constant,
$T$ is the absolute temperature, $b$ is defined as the general-order parameter (order of the kinetics), and

$$Z_m = 1 + (b-1)\frac{2kT_m}{E}$$

At $T_m$ peak position and $\beta$ heating rate the frequency factor in unit of $s^{-1}$ may also be written as;

$$s = \frac{\beta E}{kT_m^2}\cdot\frac{1}{Z_m}\exp\left(\frac{E}{kT_m}\right) \quad (2)$$

Corresponding author E-mail: w_m_eaea@yahoo.com

Eq.(1) is applicable as it has only two variables, namely; the TL intensities ($I_m$) and the temperature at the glow peak maximum $T_m$, which can be obtained directly from the experimental glow curve and the order of kinetics in general case.

The analysis of TL glow curves involving the order of kinetics must be done carefully since it is possible to get a large number of configurations, each one with a different set of parameters [5]. The incorrect selection of analysis procedure may result in very high or very low E or s. Unusual small values E may result in abnormal large values of s [5-6]. The choice of an appropriate kinetic model done with that explains the observed physical phenomena (.i.e. the model which satisfied the observed fading).

## PROCEDURES

Feldspar samples were collected from the Gattar mountain area which is located in Eastern Desert of Egypt (Gabal Gattar is bounded by longitudes 33$^o$ 13` - 33$^o$ 25` E and latitudes 27$^o$ 02` - 27$^o$ 08` N).

Each sample of feldspar represented in Fig.(1)was crushed, treated with HCl and washed with double-distilled water, then three milligrams of sieved sample of the size range 150 to 270 mesh were used. The samples were annealed (at 400$^o$C for 30 minutes) and further irradiated using gamma radiation for determination of the characteristic thermoluminescence properties. The TL glow curves were recorded using TLD reader type (THERMO scientific–Harshaw TLD model 3500) in a proper and reproducible manner. The irradiated samples were measured after fixed delayed time to uniform the decay period and to decrease the error in reading for all the samples under investigation.

## RESULTS AND DISCUSSION

The samples used are K-feldspars which have major elements concentration are listed in tab.(1),with x-ray fluorescence traces of rare earth elements were investigated with ICP-OES and listed in tab.(2). The concentration of rare earth elements (REE) plays an important role in the response of the TL materials. REE are considered the most effective elements in the shape and intensity of the TL glow curve. K-feldspar used in TL and optically stimulated luminescence (OSL) dating for years, were intensively investigated by means of TL[7-9] and spectroscopic methods [10].

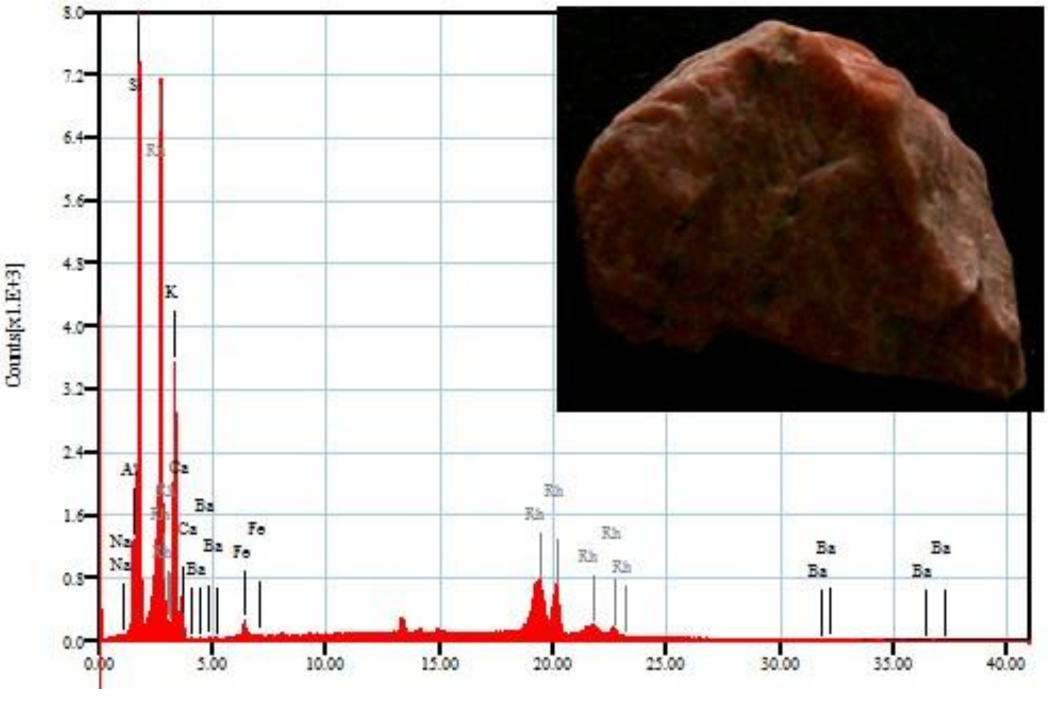


**Fig. (1)**: Spectrum of energy dispersive X-ray analysis (EDX) for feldspar.

**Table (1):** major elements concentration of K-feldspars sample.

| Element | ms% | mol% | Sigma |
|---|---|---|---|
| Na | 1.5687 | 2.1054 | 33.0561 |
| Al | 12.4932 | 14.2873 | 0.5268 |
| Si | 51.9464 | 57.0713 | 0.6635 |
| K | 32.0315 | 25.2773 | 0.6883 |
| Ca | 1.2257 | 0.9436 | 0.7033 |
| Fe | 0.4577 | 0.2529 | 0.1229 |
| Rh | Reference element | | |
| Ba | 0.2768 | 0.0622 | 0.7101 |

**Table (2):** Concentration of REEs in feldspar sample by ICP-OES.

| REE | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conc. (ppm) | 0.077 | 0.203 | 0.484 | 2.395 | N.D. | 0.192 | 0.27 | N.D. | 0.256 | N.D. | 13.99 | N.D. | 0.166 | 0.103 |

The glow curve of natural feldspar showed one single glow peak in the range of 157 °C at 10 °C/s heating rate after pre-annealing (400 °C for 30 minute) and irradiating using gamma ray dose. However the glow curve showed the summation of five different glow peaks deconvoluted by GlowFit program(11-13) as shown in Fig.(2) at 117, 146, 163, 175, 202 °C respectively at 10 Gy gamma dose.

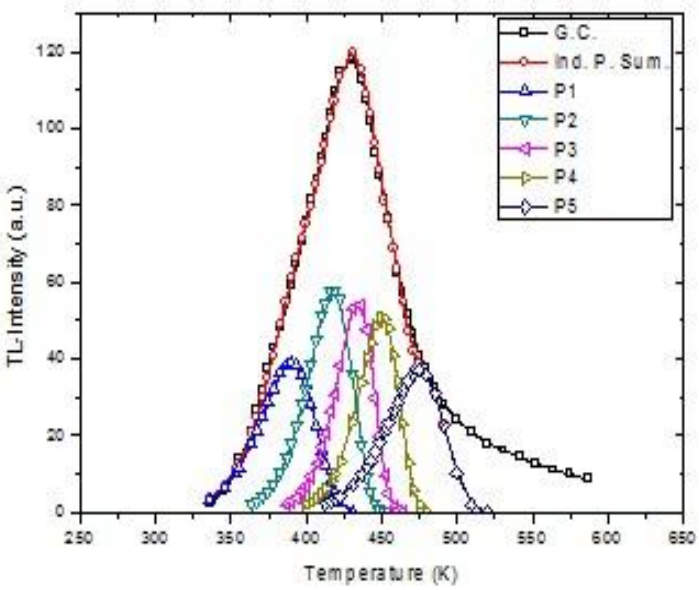


**Fig. (2)**: Glow curve of Feldspar sample.

The heating rate ($\beta$) is one of the most important experimental parameters that adversely affects the intensities of some glow peaks. The heating rates used were 1,2,4,8, and 10°C/sec. The variation rate of $T_m$ with $\beta$ is small. This type of small variation rate is also observed in natural samples like natural $CaF_2$: MBLE, Norwegian quartz and even in LiF:Mg,Ti(TLD100)(14).

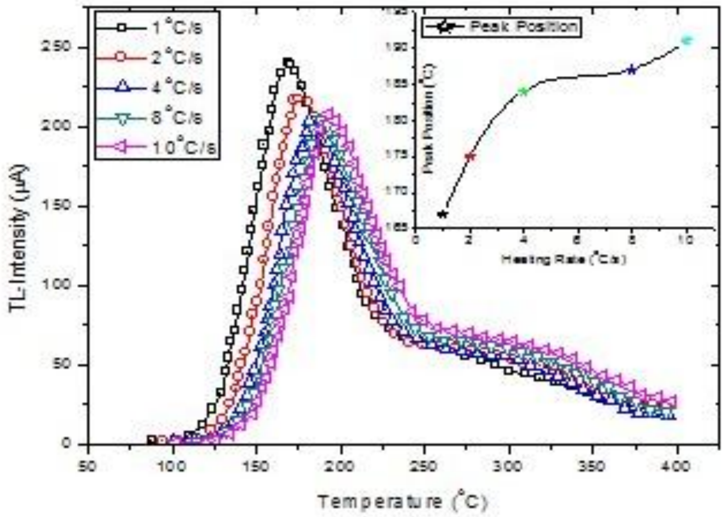


**Fig. (3)**: Heating rate effect on TL glow curve of Feldspar irradiated from 600 day by 1kGy gamma ray.

In Fig. (3), a slight increase in heating rate (β) resulted in a marked change in peak position towards deep temperature side, then afterwards it has shown some sort of stability (the rate of changing position decreased), especially after 4°C/s. On the other hand, the change that appeared in both peak area and intensity with the increase in the heating rate showed a kind of stability after 4°C/s fig.(4), for this reason 10°C/s was selected for the current investigation.

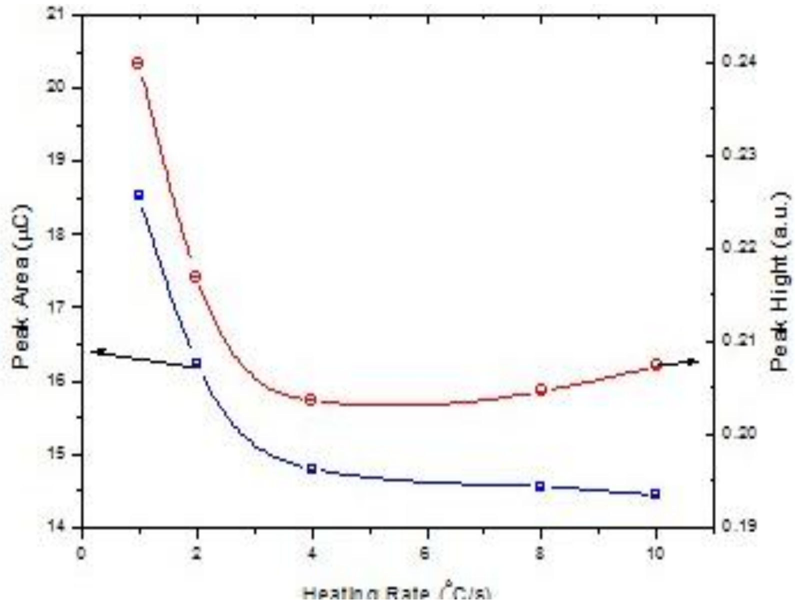


**Fig. (4)**: Heating rate effect on TL response (peak area) & peak heights of Feldspar irradiated from 600 day by 1kGy gamma ray.

Fig.(5) showed that the dose response of K-feldspar is linear from the detection limit up to about 900 Gy, the supralinear region appear within the region of 900Gy - 10kGy, then a saturating response region start to occur. The increment in the linear and supralinear region limit may be related to the low sensitivity (or number of successful trapped electrons per unit dose related to allowed centers) of the sample under investigation in comparison with the other natural TL materials like fluorspar (natural $CaF_2$) [15].

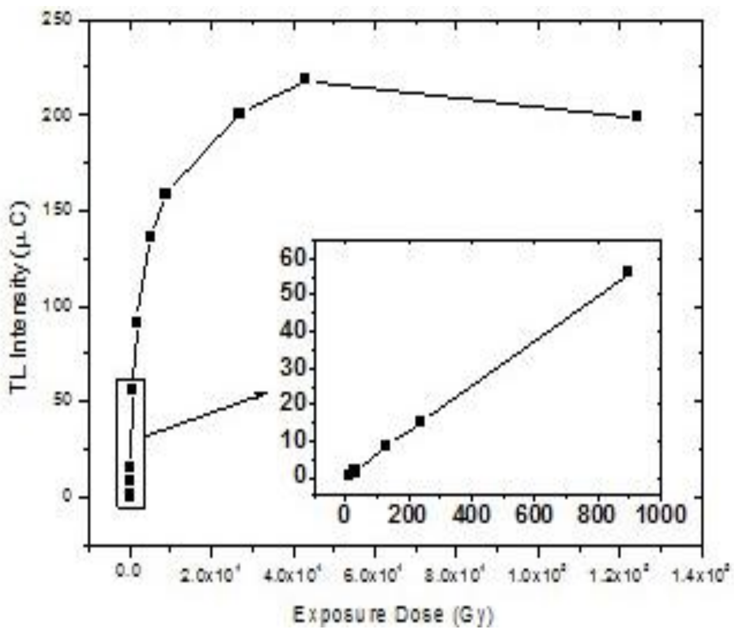


**Fig. (5)**: Dose response curves of Feldspar with gamma radiation dose.

The summation peak of feldspar behaved like non first order reaction in which the high temperature half of the curve was slightly broader than the low temperature half [16-17]. However, the peak position moved to a lower temperature with the increase in exposure dose Fig. (6).

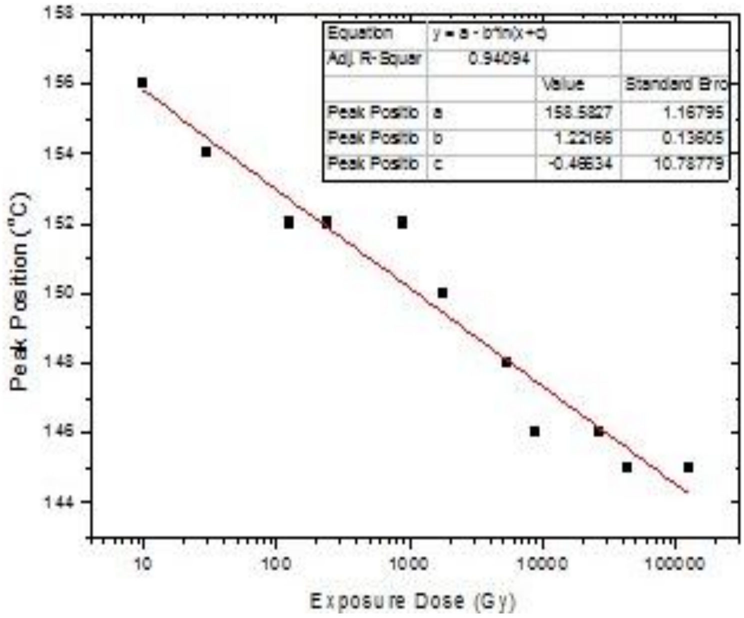


**Fig. (6):** Exposure dose effect on TL peak position of natural Feldspar.

On the contrary, the dose response curves for integrated signal of the region of interest behave more or less as that of the maximum intensity of Feldspar with gamma radiation dose (fig.(7)) within the studied range. These curves have two regions, the linear region starts with the first irradiation point (10Gy) till about 250 Gy from gamma ray, then the second of supra-linear region starts till the maximum point of irradiation in this study (45KGy).

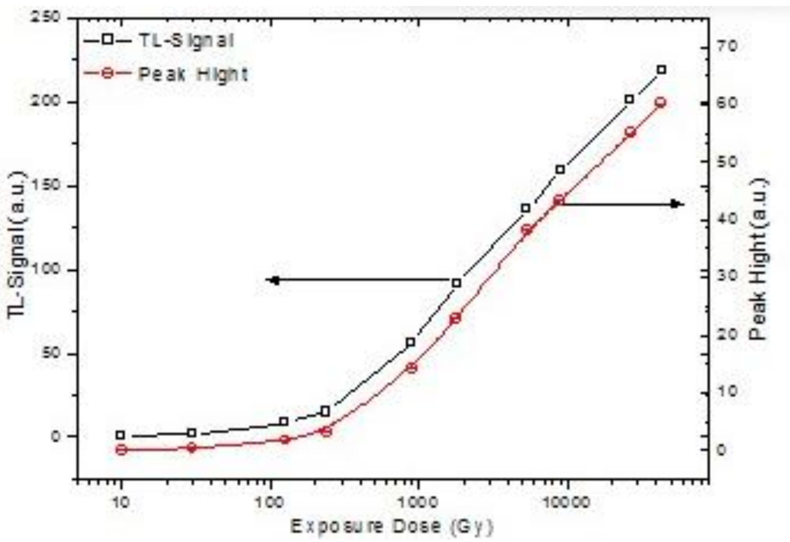


**Fig. (7)**: Dose response curves for integrated signal of the region of interest and the maximum intensity of Feldspar against gamma radiation dose.

The trapped charge within materials (before readout) can be lost by heat (thermal fading), light (optical fading) or any other means (anomalous fading) [(18)]. The feldspar samples were irradiated to 10Gy test gamma dose after pre-irradiation annealing (400°C/0.5hr). The characteristic glow curves after different storage times (at room temperature) are shown in fig.(8). It's clear from this figure that the fastest decay is in the first few hours at room temperature (RT). This thermal fading is considered to be "normal", in which the glow curve peak lies close to the room temperature. The decrease in both sides of the observed peaks decide the existence of the electron transfer between the five involved peaks.

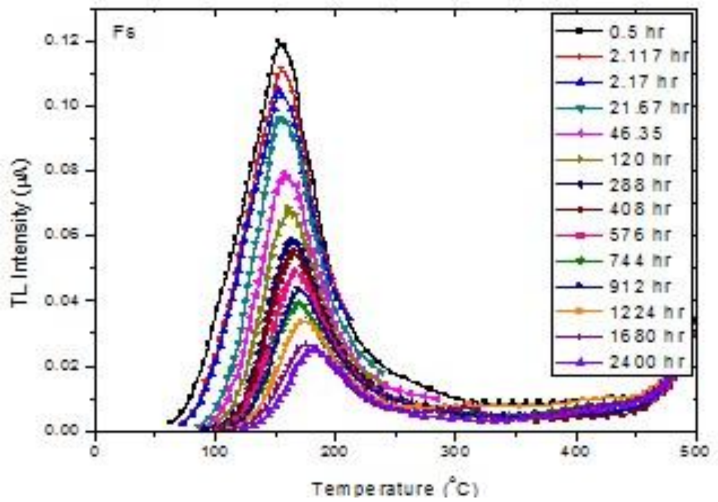


**Fig. (8)**: Characteristic glow curves of γ-irradiated Feldspar samples under normal storage up to 100 days.

Fig. (9) shows the effect of the storage time in the glow peak position. The peak position is shifted to a higher temperature along with the storage time. The shift is very high in the first hours and then the rate of change in the peak position decreases. However, the change in peak position with the storage time is related to the loss signal of the glow peaks. The loss is very high at lower temperature peaks. This behavior is recommended by the relation of the loss signal of integrated area and the maximum intensity along the storage time. It is quite convenient that after the first 100 hr of the total area decreased to about 50% and the intensity decreased to about 62% of the intensity at 0.5 hr of irradiation with 10 Gy gamma rays.

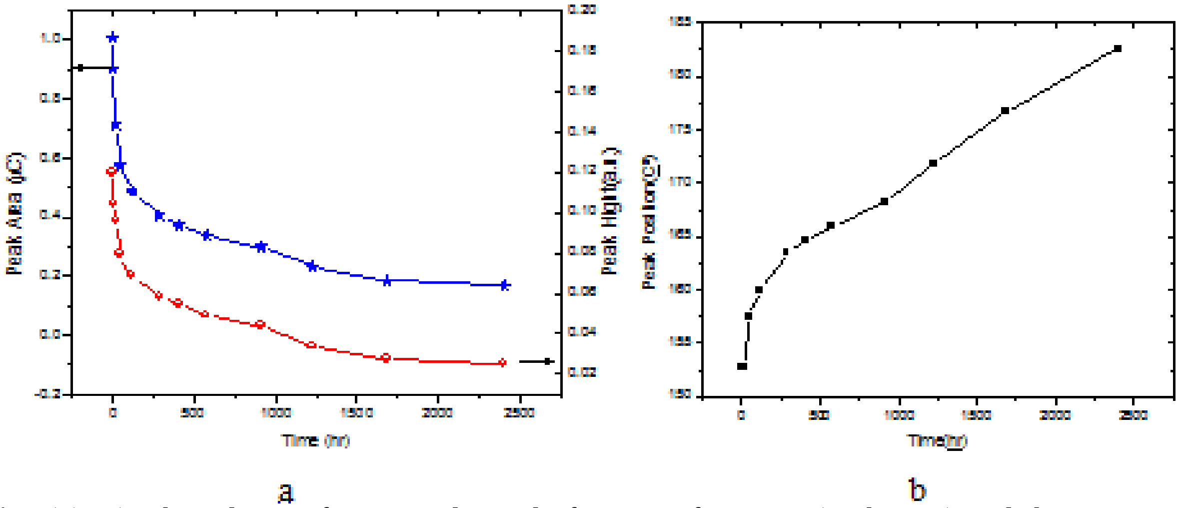


**Fig. (9)**: a) The relation of integrated signal of region of interest (peak area) and the maximum intensity (peak height), (b) Peaks position of Feldspar with storage time.

## CONCLUSION

Low thermoluminescence sensitivity of K-feldspar is improved in monitoring high dose radiation of one shot irradiation. The glow curve of K-feldspar shows one observed peak at about 157 °C which behaves like the non first order peaks. This peak is the summation of five different glow peaks at 117, 146, 163, 175, 202 °C respectively. The peak position is shifted to a higher temperature with the storage time, and the shifts have high value during the first hours following the irradiation, where the first 100 hr the total area and the intensity decreased to about 50% and 62% respectively of the original value at 0.5 hr after irradiation. The peak temperature also shifts to a higher value with decreases in TL intensity by increase the readout heating rate. The range from 4°C/s to 10°C/s shows some sort of stability in both integrated signal at the region of interest (peak area) and the maximum intensity (peak height).

## REFERENCES

(1) Chen, R. and McKeever, S.W.S., (1997), Theory of Thermoluminescence and Related Phenomena. Singapore: World Scientific.

(2) Bos, A.J.J., (2007), Theory of Thermoluminescence. Radiation Measurements, Vol. 41, pp. 45-56.

(3) Ademola, J.A. (2014) Natural Science, 6, 1037-1043.

(4) Ros, J.M. Gomez and Kitis, G., (2002), Radiat. Prot. Dosim., Vol.101, pp.47-52.

(5) Furetta, C., (2003), Hand Book of Thermoluminescence. World Scienctific Publishing,Singapore.

(6) Levy, P. W., (1984), Nuclear Instruments and Methods in Physics Research B, Vol. 1, pp. 436-444.

(7) Ahmed A.B., Gartia R.K., (1985) Phys. Stat. Sol. A 94 645.

(8) Strickertsson K., Nucl. (1985) Tracks Radiat. Meas. 10 613.

(9) Kirsh Y., Shoval S., Townsend P.D., (1987) Phys. Stat. Sol. A101 253.

(10) Visocekas R., Tale V., Zink A., Spooner N.A., Tale I., (1996) Rad. Prot. Dosim. 66 391.

(11) Bilski, P., Budzanowski, M. and Olko, P., (1996), Radiat. Prot. Dosim., Vol. 65, pp.195-198.

(12) Bilski, P., (2002), Radiat. Prot. Dosim., Vol. 100, pp. 199-206.

(13) Puchalska, M. and Bilski, P., (2005), Kraków, Vol. 37, Issue 5, pp. 1-17.

(14) Kitis, G., Spiropulu, M., Papadopoulous, J. and Charalambous, Stef., (1993), Nuclear Instruments and Methods in Physics Research, Vol. 73, pp. 367-372.

(15) Madcour, W. E., El-Kolaly, M. A., Henaish, B. A., Abo-Zeid, H. M., Afifi S. Y. and Abd Al-Maksoud , T. M., (2013). Journal of Nuclear and Radiation Physics, Vol. 7, No. 11.

(16) Furetta, Claudio, (2010), Handbook of Thermoluminescence-World Scientific.

(17) Bos, A. J. J., (2001), Nuclear Instruments and Methods in Physics Research Section B: , Vol. 184, Issues 1–2, pp. 3–28.

(18) McKeever, S.W.S., (1985), Thermoluminescence of Solids. Cambridge University Press.