A SEMI-EMPIRICAL FORMULA FOR THE EXPRESSION OF TL FADING OF NATURAL DOLERITE

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Abstract

The TL fading trend of natural dolerite samples obtained from Abeokuta in South Western Nigeria for varying post annealing irradiation doses and varying post irradiation storage times prior to readout has been investigated with a view of establishing a semi-empirical formula that best describes this phenomenon in this natural rock. The measurements indicate room temperature fading (25-27 °C) of averagely 8% for the first 1 week then a further 3% in the following week followed by saturation for the next 1 month. A general TL response $(TL)_D$ of the phosphor (dolerite) irradiated to any gamma radiation dose D (Gy) was obtained as $(TL)_D = AT^{-b}$. A, is an integer which is constant for a particular gamma irradiation dose regardless of the post irradiation storage period T in days before the readout while the exponential b is the specific negative index of T.

1. Introduction

In an earlier investigation, Ogundare *et al.* (2004) examined the TL characteristics of natural dolerite obtained from South West Nigeria. They discovered that this material is suited for high dose measurements. Strong TL signal fading within the first one week followed by stable response for the next one month was also observed. In that work, the effect of possible drift of the TL reader was not taking into consideration.

The present investigation takes cognizance of the aforementioned effect of a possible drift of the TL reader by examining in detail through exposing the samples to varying gamma irradiation doses at different periods of time prior to readout and having the readout performed at nearly the same time for all the samples (Furetta *et al.*, 2000). Specifically, the TL response of this natural rock with varying post annealing irradiation doses for varying post irradiation storage times was carried out and a semi-empirical formula that reliably predicts how this material will behave after having been irradiated and then stored for a given time before readout presented.

2. Experimental Method

Some quantity of dolerite obtained from Abeokuta in South West Nigeria were pulverized using a thoroughly acetone cleaned pulverizer. Pre-irradiation annealing was carried out in order to eliminate the effects of any previous exposure (El-Faramawy, 2000) at the Federal Radiation Protection Service, department of Physics, University of Ibadan, Nigeria using the DA Pitman programmed thermoplate annealing oven. The oven was preset to a temperature of 400 °C and a time of 2 hours.

11 mg aliquot of 9 batches each of three slots of the annealed dolerite samples were irradiated for varying periods of time (Table 1) using a ^{60}Co gamma cell irradiator. This facility available at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria at the time of this investigation has a dose rate of 6.511 $Gy(min)^{-1}$. The variously irradiated samples were then wrapped in thick black cellophane bags to eliminate the effect of sunlight since optical energy is also associated with the stimulation of trapped charge carriers leading to the observation of thermoluminescence (Mckeever, 1983). They were then placed inside a dessicator to minimize the effect of humidity and subsequently stored at room temperature. Although the literature (Oberhofer and Scharmann, 1979) indicates that TL dosimetry is generally independent of humidity, it was assumed that this might not be true for dolerite especially as it has been found not to be true for lithium borate chips ($Li_2B_4O_7 : Mn$). Storage at constant temperature (room temperature) eliminates the proven effects of temperature to fading which is evident from the relationship (Oberhofer and Scharmann, 1979):

$$P = Se^{-\frac{E}{kT}} \qquad (1)$$

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P is the transition probability, S the vibrational factor (s^{-1}) characteristic of each center and E the activation energy (trap depth) in eV. T represents the storage temperature (K) while k is the Boltzmann's constant in evK^{-1}. The stored samples were then readout after a post-irradiation storage period of one month using a Victoreen reader model 2800M also available at the CERD. The entire process was repeated for storage periods of 3weeks, 2 weeks, 1 week and 1 day. The mean TL responses of the variously irradiated samples were plotted against post irradiation period. The relationship between TL response and post irradiation storage period was then deduced by curve fitting.

The TL measurements were all made from a pre-heat temperature of 50 °C and a linear temperature rate of 8 $°Cs^{-1}$ for a maximum temperature of 400 °C. During each readout, the reader was interfaced with an IBM compatible PC for data storage and glow curve analysis via an RS232 port. The heating chamber of the TL reader (planchet) was connected to a supply of high purity, dry nitrogen gas to reduce chemiluminescence in the heated samples. All facilities employed in this investigation had been used by other investigators (Balogun *et al.*, 1999; 2004).

3. Results and discussion

The mean response of the variously irradiated phosphor samples after varying post-irradiation storage periods are presented in Table 1. Each reading represents an average of three readings. The results indicate room temperature fading (25-27 °C) of averagely 8% for the first 1 week then a further 3% in the following week followed by saturation for the next 1 month. This trend agrees with the observations of Ogundare *et al.* (2006). As illustrated in figure 1, the trend is observed for the variously irradiated samples regardless of the post irradiation storage time before readout. Typical glow curves showing the response of the material after one, two and three weeks post irradiation storage before readout are shown in figure 2. The figure indicates that the sample stored for 1 week has a maximum intensity of 2.5 (AU). This occurred at a temperature of 186 °C. On the other hand, the corresponding values for the 2 and 3 weeks stored samples are 2.1 (AU) at 195 °C and 1.4 (AU) at 195 °C respectively. Thus there is a right tended shift in the maximum intensities towards higher temperatures indicating the presence of shallow as well as deep traps in the sample. The shape of these glow curves also indicate first-order kinetics.

The general fade equation for these curves is given by:

$$(TL)_D = AT^{-b} \tag{2}$$

$(TL)_D$ represents the response of the phosphor (dolerite) given a gamma irradiation dose D (Gy). A, an integer which is constant for a particular irradiation dose regardless of the storage period T in days before the readout and the exponential b, the specific negative index of T. T ranges from 1day to 1month. The values of A and b as determined from the equations of the fading curves for the variously irradiated samples are presented in Table 2.

4. Conclusion

A fairly strong room temperature (25-27 °C) fading of 8% for the first 1 week then a further 3% in the following week followed by saturation for the next 1 month was observed for the variously irradiated samples regardless of the post irradiation storage period before readout. Irrespective of the post-irradiation storage time prior to readout, a general TL fading equation $(TL)_D = AT^{-b}$ obtained in this work, empirically describes the TL response of this natural rock sample.

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Table 1: TL fades for variously irradiated dolerite samples for varying storage periods

γ-Irradiation Dose (kGy)	Mean TL Response (AU) after varying storage periods				
	1 Day	1Wk.	2Wks.	3Wks.	1Mnth.
Unirradiated	0.6272	0.329	0.283	0.1071	0.07195
0.03	38.346	4.87529	2.2425	1.6832	1.05735
0.13	48.956	13.53402	8.3971	6.622	5.2775
0.39	79.717	34.60098	24.724	23.72175	18.076
1.17	89.023	73.67243	71.788	68.028	59.625
2.34	191.123	130.329	118.837	113.434	103.625
3.12	196.086	165.379	148.184	142.9055	111.13
3.92	270.640	176.747	156.851	161.7905	124.087
9.37	303.348	235.313	202.295	180.7964	160.318

Table 2: Fit parameters for the varying dolerite fade curves

γ-Irradiation Dose (kGy)	A	b
0 (unirradiated)	0.7773	0.5881
0.03	38.346	1.0599
0.13	48.956	0.6645
0.39	79.716	0.4289
1.17	113.650	0.1801
2.34	189.450	0.1777
3.12	204.540	0.1410
3.92	270.640	0.2067
9.37	314.080	0.1814

Fig. 1: TL response of variously irradiated dolerite after varying storage periods

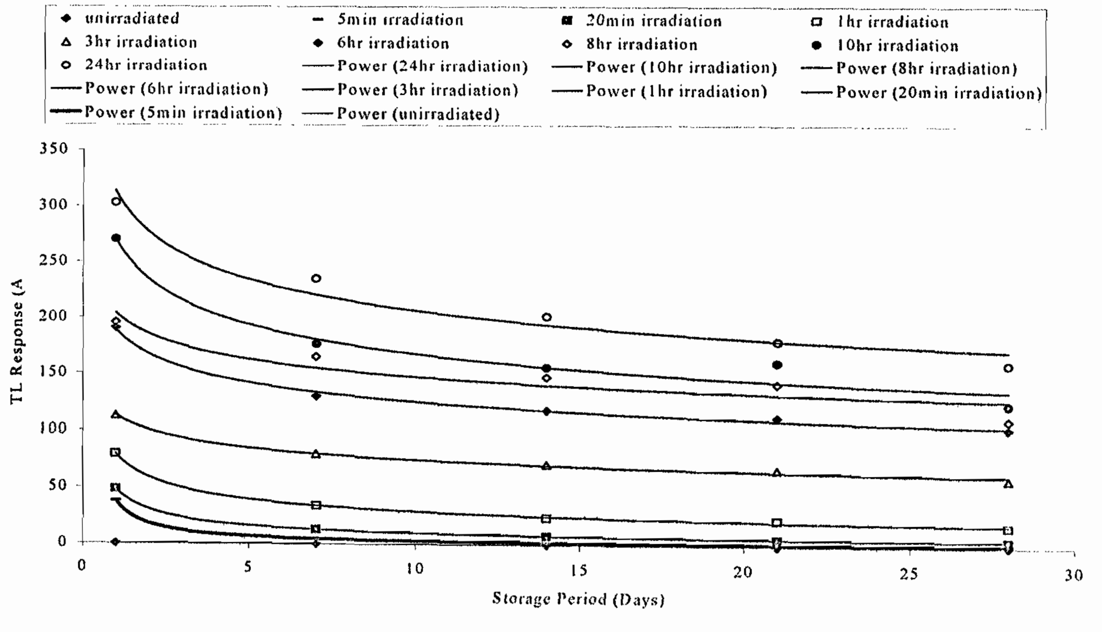

Fig. 2: Typical dolerite glow curves for varying post irradiation storage periods