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A STUDY OF THE THERMOLUMINESCENCE FADING CHARACTERISTICS OF NATURAL MARBLE PHOSPHOR

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ABSTRACT
The thermoluminescence (TL) response fading behaviour of natural marble obtained from the South Western Basement Complex of Nigeria for varying gamma irradiation doses were investigated for the purpose of ascertaining if this material can suffice as a TL dosimeter. Irradiation was done using a ^{60}Co *gammacell irradiator while a Victoreen TL Reader was employed for the TL measurements. The result indicate that the material exhibits a logarithmically exponential decay having the equation TL (Au) =* $-7.02\ lnT_s + 71.11$*. Fading is observed to be initially fast then gradual and thereafter almost constant after about one month post irradiation storage like is characteristic of most common TL dosimeters. The result also shows that of the three peaks revealed by the analyzed glow curve of this TL phosphor, the lower temperature peak occurring at 115 °C is most suitable for this dosimetric application.*

Key words: Fading, Natural marble, Thermoluminescence.

INTRODUCTION

Nigeria is currently located in the midst of countries that have one or more nuclear facilities (Tran, 2007). Such include Morocco, Algeria, Libya, Egypt etc. On her part, her first nuclear research reactor, the Nigeria Research Reactor I (NIRR-1) located at the Centre for Energy Research and Training (CERT) Ahmadu Bello University Zaria has since gone critical. The country has also sought the support of the International Atomic Energy Agency (IAEA) to develop plans for up to 4,000 MW of nuclear capacity by 2027 for the purpose of electricity generation (WNA, 2010).

Nuclear facilities have tendencies of releasing radioactive effluents to the immediate environments and beyond. This may be in the form of leakages, accidental fallouts and disposal of nuclear waste. Any of these can pose regrettable environmental and health incidences of varying proportions. A typical example is the Fukushima Diachi nuclear accident in Japan.Nuclear fall-outs are not known to have any regard to national and international boundaries and although the nuclear power industry has proposed new safer facilities design, error free construction may not be guaranteed and so there could be no end to nuclear accidents (Jacobson, 2010). It is therefore necessary that as the country gets more involved in nuclear applications, readily available TL dosimeters be sourced and developed for use in the events of any nuclear or radiological accidents especially as the cost of procurement of these dosimeters from the relevant locations in the advanced countries is very costly and cumbersome.

In response to this radiation protection challenge, a number of investigators have studied the dosimetric potentials of certain natural materials (Ogundare et al., 2004; 2006; Ige et al., 2006; Fasasi et al., 2007). Some others have also examined the potentials of a variety of household and laboratory materials such as cane sugar, egg shell and chalk (Iyang et al.,2011).

It has been established that in addition to the known conventional uses of natural marble for example in structural engineering, this rock in its phosphor form is a probable TL dosimeteric material appropriate for use in high dosimetry especially in dose reconstruction after a nuclear or radiological accident (Mokobia, 2010). Since in TL dosimetric considerations, the stability of the TL response of the dosimeter after exposure to a given stimulus is a major indicator of the suitability or otherwise of the material, this investigation therefore examined the TL fading behaviour of this probable high dosimetric natural material.

MATERIALS AND METHODS

The marble samples were obtained from the South Western Basement Complex located between latitude 7-10^{o} N and longitude 2-5^{o} E. The obtained samples were thoroughly cleaned using acetone, crushed and then air dried to constant weight at room temperature (RT). They were then pulverized out using a thoroughly acetone cleaned pulverizer and were immediately subjected to pre-irradiation annealing which was carried out using the DA Pitman programmed thermoplate located at the Nigeria Nuclear Regulatory Agency (NNRA), University of Ibadan, Nigeria at a temperature of 400 ^{o}C for 2 hours. This annealing was to ensure that the effects of any previous exposure were eliminated (EL-Faramawy et al., 2000). The annealed samples were then cooled at RT, and then packed into a number of properly labeled dispensing polyethylene sachets and stored in a dessicator so as to exclude moisture. 11 mg aliquot of 15 batches each of three slots of the annealed samples were weighed out using a highly sensitive moisture free Metler top loading electronic balance. Each of these was then irradiated for 15 min in a ^{60}Co gammacell 220 irradiation facility at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria. The irradiated samples were then stored at RT in a dessicator to exclude moisture. The TL response of each of these samples was then readout after different post- irradiation storage periods ranging from 5 min to 5 weeks using a Victoreen reader model 2800M also available at the CERD. These TL measurements were carried out using a pre-heat temperature of 50 ^{o}C and a linear temperature rate of 8 ^{o}C per sec for a maximum of 400 ^{o}C.

RESULTS AND DISCUSSION

The obtained readouts for the various post irradiation storage periods are given in Table 1 while the investigated relationship between signal/TL response and post exposure/irradiation (fading trend) is shown in Figure 1. This scatter diagram predicts that the loss of TL response with post irradiation storage time T_s (days) is logarithmically exponential having a fitted decay equation: TL (AU) = $-7.02 \ln T_s + 71.11$ [1]

This decay portrays a fading trend which is initially fast then gradual and thereafter almost constant after about one month post irradiation storage. This trend is characteristic of common radiation dosimeters. For example, a similar fading trend had been established for natural dolerite (Mokobia et al., 2006).

The TL glow curve analysis of the irradiated/exposed samples reveals the presence of

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three peaks at 115 ^oC, 165 ^oC and 280 ^oC as shown in Figure 2. The number of glow peaks observed in this investigation for Nigerian marble agrees with that observed for marbles obtained elsewhere (Bruce et al., 1999 and Polikreti et al., 2003).

The TL responses of each of these revealed peaks from immediately after to one month after irradiation are given in Table 2. The fading trend of each of these peaks, obtained by plotting each of their responses against storage period (days) is shown in Figure 3. It is observed that from immediately after irradiation to the first day of post irradiation storage, the loss of TL response by the peaks are 49%, 166% and 67% for peaks 1,2 and 3 respectively. Thereafter the decay remained constant for each of them. Consequently it can be adduced that the lower temperature glow peak (peak 1) occurring at 115 ^oC is most suitable for the TL dosimetric application of marble phosphor.

Table 1: Marble TL response for varying post irradiation storage periods

Post irradiation storage period (days)	Mean TL response (AU)	Post irradiation storage period (days)	Mean TL response (AU)
0(Just after irradiation)	113.53	3	60.57
0.01	103.92	7	56.09
0.02	103.45	15	52.06
0.04	92.37	20	50.62
0.21	82.33	25	49.53
0.43	70.67	30	48.65
2	67.73	37	47.67

Table 2: TL response of the observed peaks

Storage period (days)	Peak 1 (AU)	% Fade	Peak 2 (AU)	% Fade	Peak 3 (AU)	% Fade
0(Just after irradiation)	0.7005		1.910		0.985	
1	0.218	49	0.250	166 >100	0.311	67
7	0.218	49	0.167	174 >100	0.295	69
14	0.218	49	0.167	174 >100	0.295	69
21	0.218	49	0.167	174 >100	0.295	69
28	0.218	49	0.167	174 >100	0.295	69

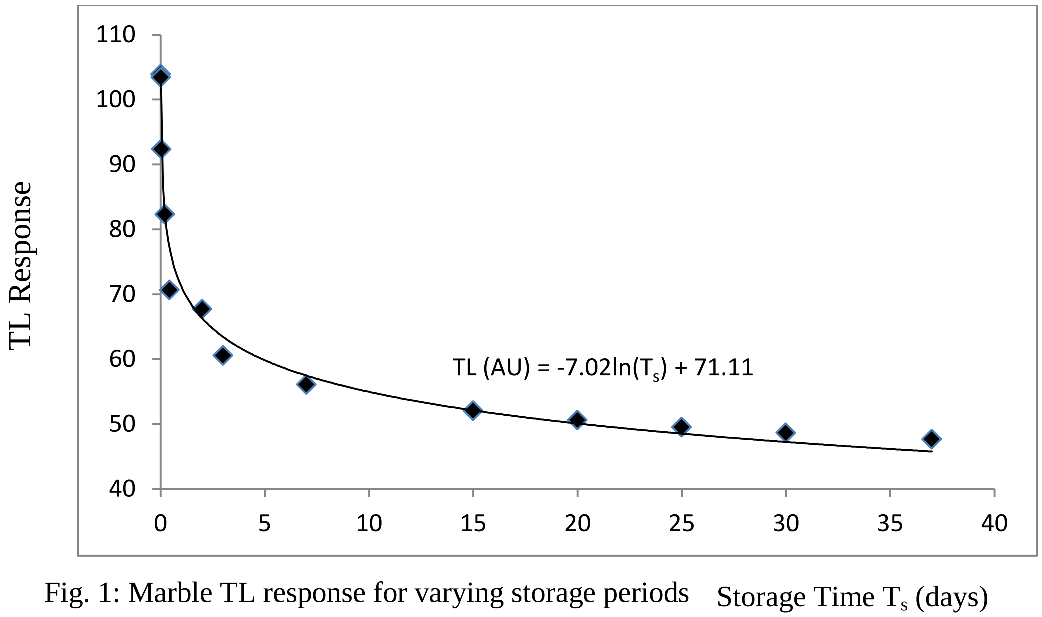

Fig. 1: Marble TL response for varying storage periods

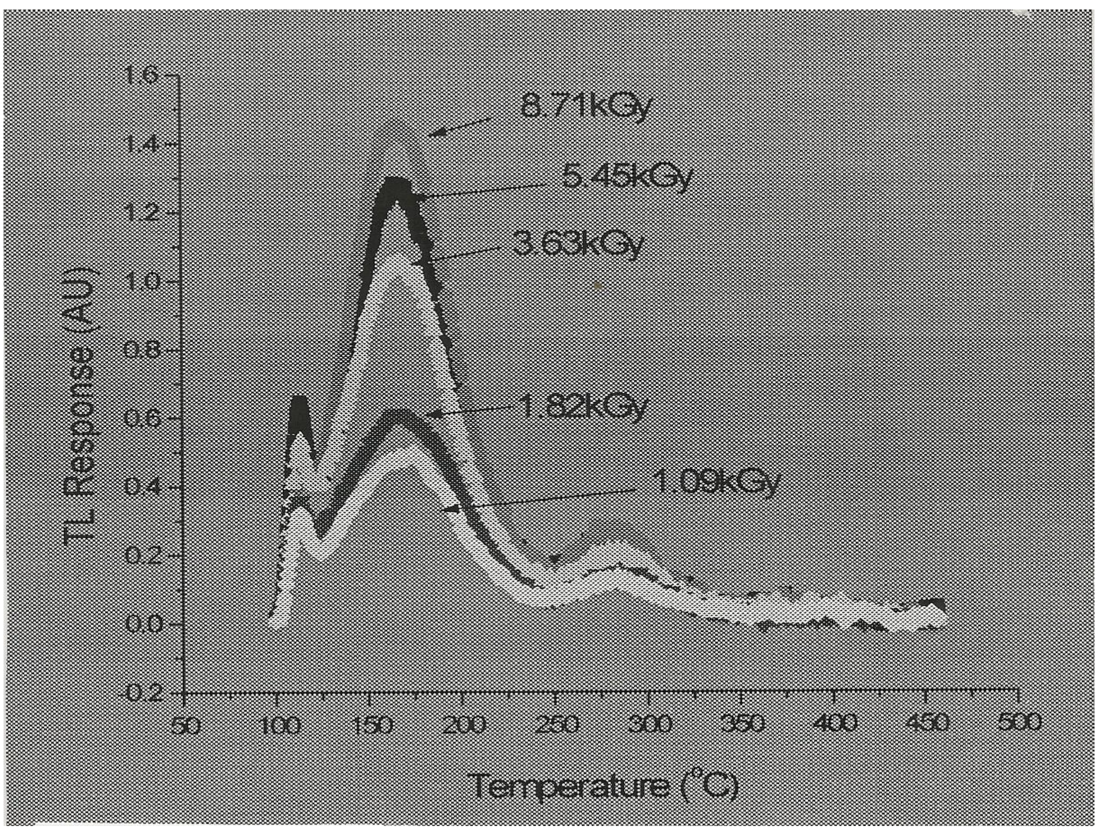

Fig.2: Glow curve characteristics of natural marble

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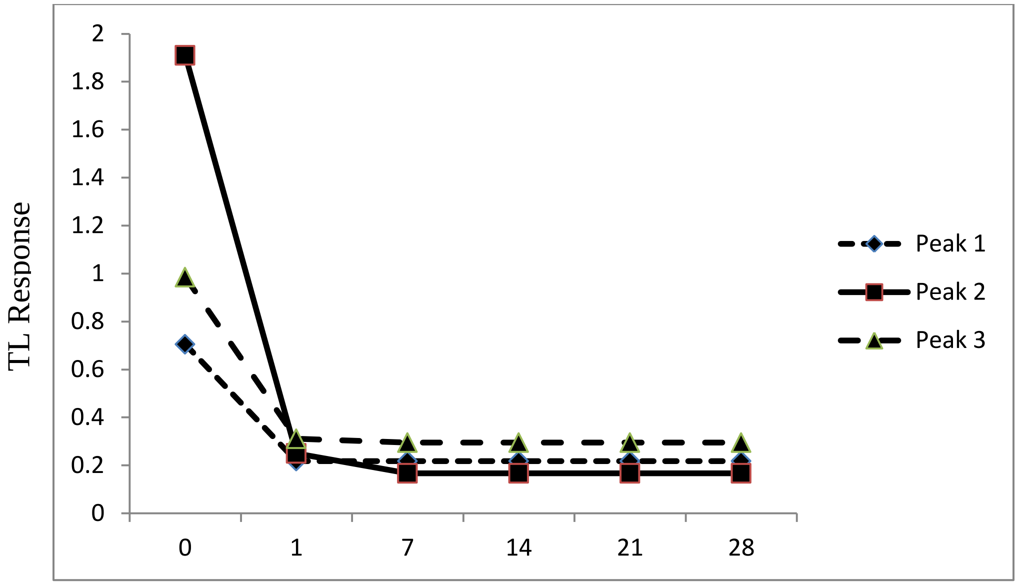

Fig.3: Fading Trends of the three TL glow peaks   Storage Time T_s (days)

From the result of this study it can be concluded that on the basis of the trend exhibited in its loss of signals with time/fading after exposure, natural marble phosphor suffices as a suitable retrospective TL dosimeter. This dosimetric application is associated with its glow curve peak at the temperature of 115^{o}C.

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