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ORIGINAL ARTICLE

A Correlation: TL response of synthetic fused quartz with ^{60}Co gamma (high dose) source and ^{90}Sr/ ^{90}Y Beta (low dose) source

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ABSTRACT

The correlation between TL response of synthetic fused quartz with ^{60}Co gamma source and ^{90}Sr/^{90}Y beta source are discussed. In the present study the thermoluminescence response of two batches of synthetic fused quartz irradiated simultaneously with gamma and beta rays were obtained with Thermo Electron Corporation manual TLD Reader Model number 3500 TLD reader. The result revealed that this phosphor tends to exhibit a very close TL glow shapes for different test doses using the two irradiation sources. There seems to be a significant relationship in the dose response and the fading of the phosphor with the different irradiation sources. The seeming distinct properties of this phosphor with the two types of irradiators suggest the suitability of this material for mixed radiation dosimetry.

Key words: Beta rays, Dose response, Synthetic Fused quartz, Gamma rays, glow curve

1. INTRODUCTION

In search for possible natural dosimeters for measuring natural occurring ionizing radiation quartz and feldspar have been seen as possessing the thermoluminescent characteristics [1]. For both materials the setback is enormous. It is known that most feldspars are prone to anomalous fading [2]; i.e. the unexpected loss of charge carriers responsible for high temperature TL traps, this makes them unsuitable for dating. The other disadvantage of feldspar when compared with quartz is that the TL signals of feldspar show strong bleaching effect in sunlight [3]. The rate of bleaching varies from one sample to another. Quartz is mostly considered in dating and retrospective dosimetry because it is one of the most abundant minerals on earth, is present in most of the samples useful in luminescence studies, [3]. Natural quartz can thus be used as a natural dosimeter for quantifying the radiation history of materials. It is used in a variety of applications such as testing the authenticity of art objects, nuclear accident dosimetry, food irradiation control, and in particular for the dating of geological and archaeological materials. However, natural quartz has major disadvantage which hindered it has been regarded as universally acceptable dosimeter due to the fact that natural quartz is a natural material, it is expected that the number and nature of the lattice defect will be highly variable with geological origin and history of the individual quartz grains. This variability has resulted in the turning down of natural quartz as universal dosimeter. For the above mentioned reasons, it is desirable to investigate alternative quartz (synthetic fused quartz) for possible usage as a dosimeter for low and high dose measurement. Synthetic fused quartz is made from the treatment of crushed natural quartz with hot aqueous solution of a base such as sodium hydroxide. Synthetic Fused quartz have many advantages compared to natural quartz; these include: (1) a higher intrinsic luminescence sensitivity implying and improved minimum detection limit; (2) the luminescence signals from synthetic fused quartz have been reported to grow higher than natural quartz, providing a potential extension of the usable dose range; and (3) synthetic fused quartz unlike natural quartz has two well distinct peaks [4]. Since the TL properties of synthetic fused quartz have been shown to be much closed to that of the commercially available LiF [5].

The trust of the present work is to correlate the response of synthetic fused quartz using two different irradiation sources i.e. ^{60}Co and ^{90}Sr/^{90}Y for possible application in high and low dose measurement. There exists a very wide difference between the ^{60}Co and ^{90}Sr/^{90}Y. ^{60}Co has a half-life 5.27 years with maximum energy of β particles 314 keV and are also accompanied by γ rays with energies of 1173 keV and 1332 keV. The radiation of ^{90}Sr/^{90}Y source consist of Strontium particle with half-life 28.6 years with maximum energy of β particles with energy 546 keV and β particles of daughter nuclei Yttrium with half-life of 64 hours having a maximum of the β particles 2270 keV.

2. EXPERIMENTAL DETAILS

The synthetic fused quartz use in the present study was used as received 3 X 3 X 1 mm^3 in dimension with an average mass of 7.92 ± 0.34 mg. The source, other manufacturing details and elemental composition of this material is reported elsewhere [4]. The sets of these materials were initially washed with detergents and rinsed many times with doubly de-inonized water to ensure the removal of any surface contaminant. In this work, the set comprising of about 20 of these glasses were annealed at 400 ^{o}C for 1 hr using the DA Pitman programme thermo-plate annealing oven at Centre for Energy Research and Development Obafemi Awolowo University Ile-Ife (CERD). This oven used for the annealing/heat has accuracy better than $\pm 1^o C$. Different sets of synthetic fused quartz were simultaneously irradiated with ^{60}Co gamma cell 200 and ^{90}Sr/^{90}Y sources having a dose rate of 6.05 Gy/min and 40 μGy/min respectively. TL measurements were made using a Thermo Electron Corporation manual TLD Reader Model number 3500 TLD reader available at CERD with WinREMS™. TL measurements were performed mostly using a 50 ^{o}C preheat temperature and a maximum temperature of 400 ^{o}C. The preheat temperature was later adjusted to 150 ^{o}C and the 400 ^{o}C maximum temperature was maintained. In all measurement, a linear heating rate of 5^{o}C/s was employed. All the measurements were made in a nitrogen atmosphere at the flow rate of approximately 2.5 Ls^{-1}. For each TL reading, two measurements were made one after the other. In each case, the second measurement was subtracted from the first in order to correct for the effect of blackbody radiation from the sample holder.

3. RESULTS AND DISCUSSION

Glow curves features

Our results revealed a very close similarity in shape of the glow curves obtained using the two distinct irradiation sources. Figures 1 and 2 show the glow curves of the synthetic fused quartz after exposure for 1 hour (363 Gy and 2.4 mGy) with ^{60}Co and ^{90}Sr / ^{90}Y sources in that order, using the same heating rate of 5 ^{o}C/s and 50 ^{o}C preheat. The glow curves of the fused quartz look so how comparable to that obtained for the heating rate of 8 ^{o}C and 10 ^{o}C for this glass [4]. The glow curve obtained using the ^{90}Sr/ ^{90}Y differs only slightly especially for the peak at about 400 ^{o}C for 50 ^{o}C pre heat. The two peaks exhibited by the phosphor are very pronounced with the readjustment of the pre heat from 50 ^{o}C to 150 ^{o}C (Figures 3 and 4). It appears that there is not much different in the position of the two peaks with the readjustment in the pre heat from 50 °C to 150 °C. The almost similarity in the shape of the glow curve as obtained using different irradiation sources having different energies is as expected because the mode of excitation of gamma and beta ray are the similar [6-7].

Dose response

The dose response of the synthetic fused quartz was studied over the dose range of 0.0024 -0.87112 Gy of ^{90}Sr / ^{90}Y beta source and 363 - 1.3 kGy of ^{60}Co gamma source.

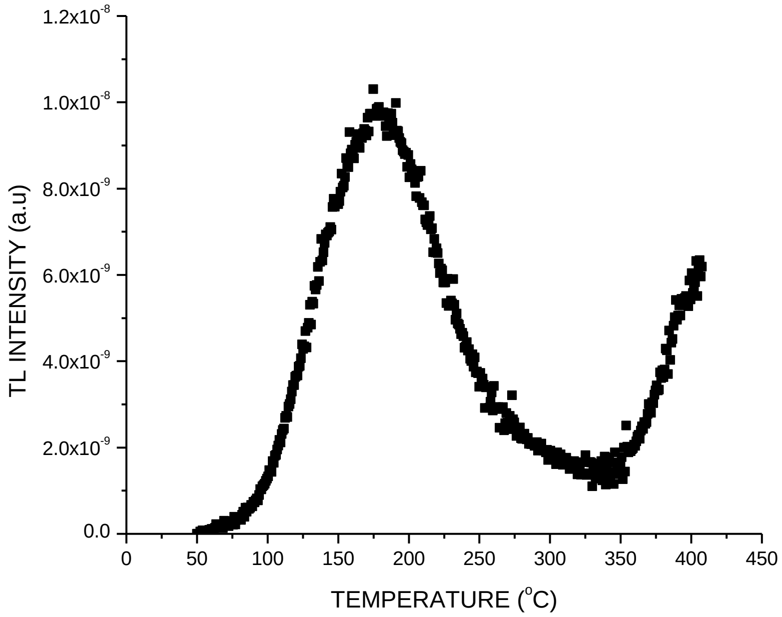

Fig.1: Glow curve of synthetic Fused quartz with 5 °C/s heating rate using ^{60}Co with irradiation for 1h

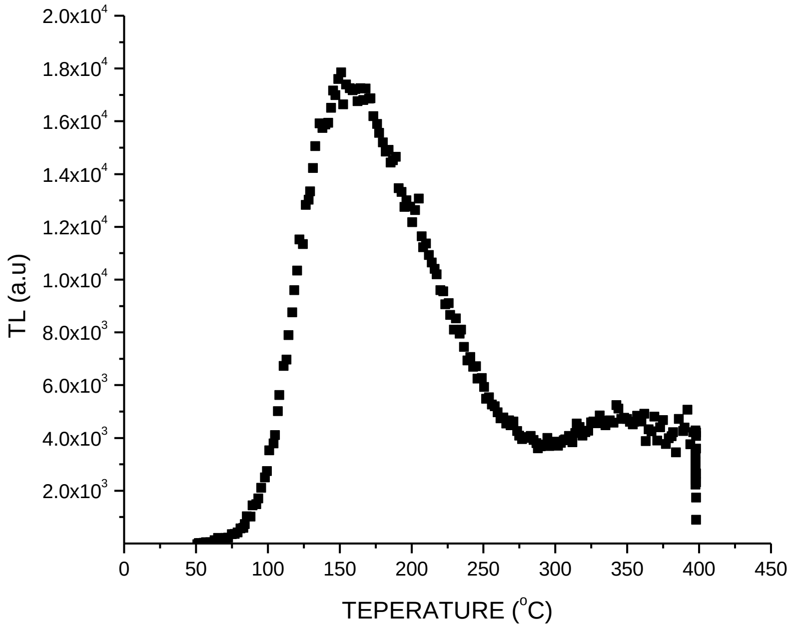

Fig. 2: Glow curve of synthetic Fused quartz with 5 °C/s heating rate using $^{90}Sr/^{90}Y$ source with irradiation for 1 h

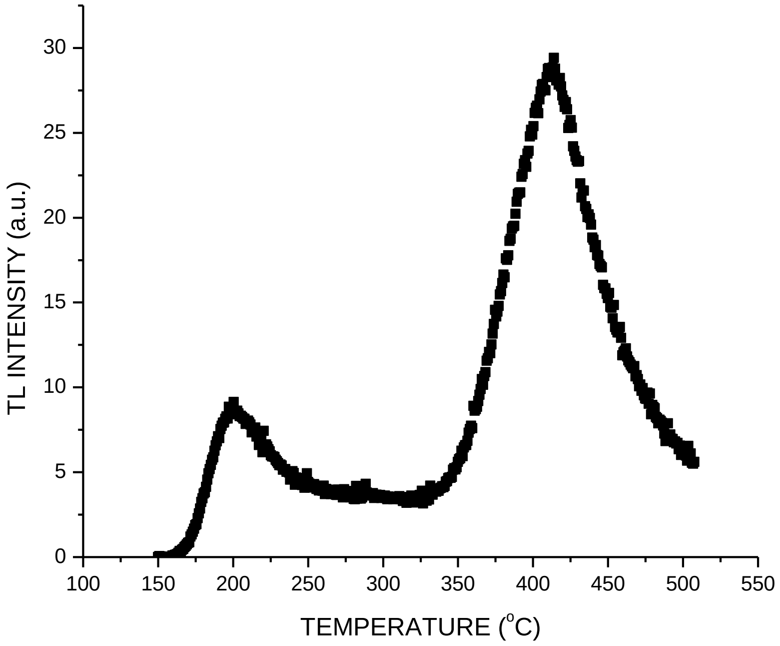

Fig. 3: Glow curve of synthetic Fused quartz with 5 °C/s heating rate and 150 °C preheat using ^{60}Co source with irradiation for 1 h

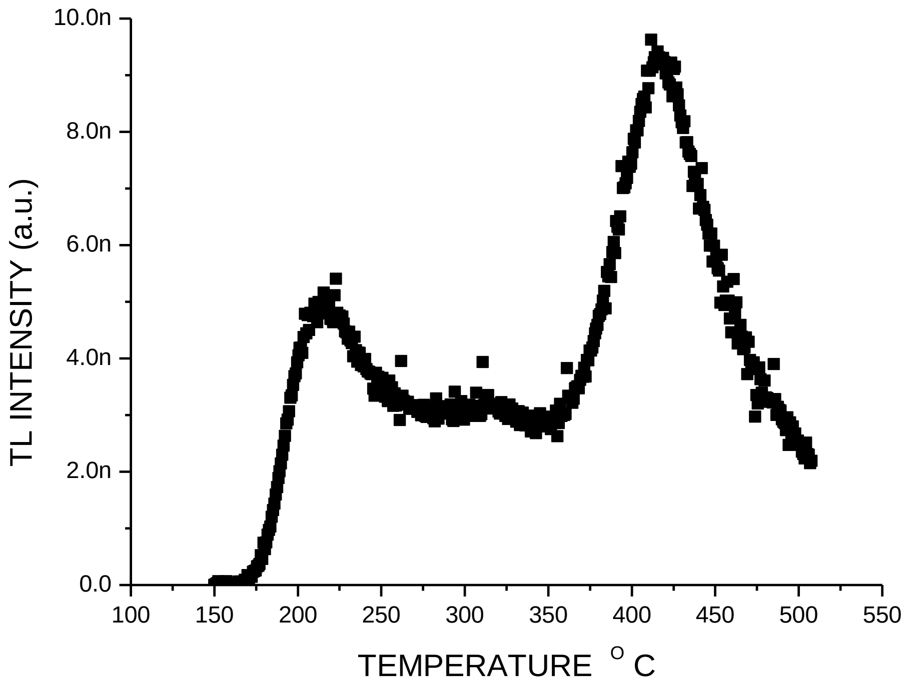

Fig.4: Glow curve of synthetic Fused quartz with 5 °C/s cycle time and 150 °C preheat using ^{90}Sr/^{90}Y source with irradiation for 1 h

The overall trend in the dose response curve of synthetic fused quartz has really revealed the positive dosimetric properties of this phosphor. For example, a good response was obtained for each of the irradiation sources, as also confirmed by the very positive R^2 correlation coefficient (Fig. 5). This observation is interesting, because unlike natural quartz which is known to have saturation at about 200 Gy, synthetic fused quartz exhibited a linear dose response at few kilo gray irradiations for the gamma ray irradiation. Our data has shown relative linearity for both gamma and beta source within the dose range of investigation. The only noticeable difference in our data has been the fact that the gamma dose showed higher magnitude of the dose response.

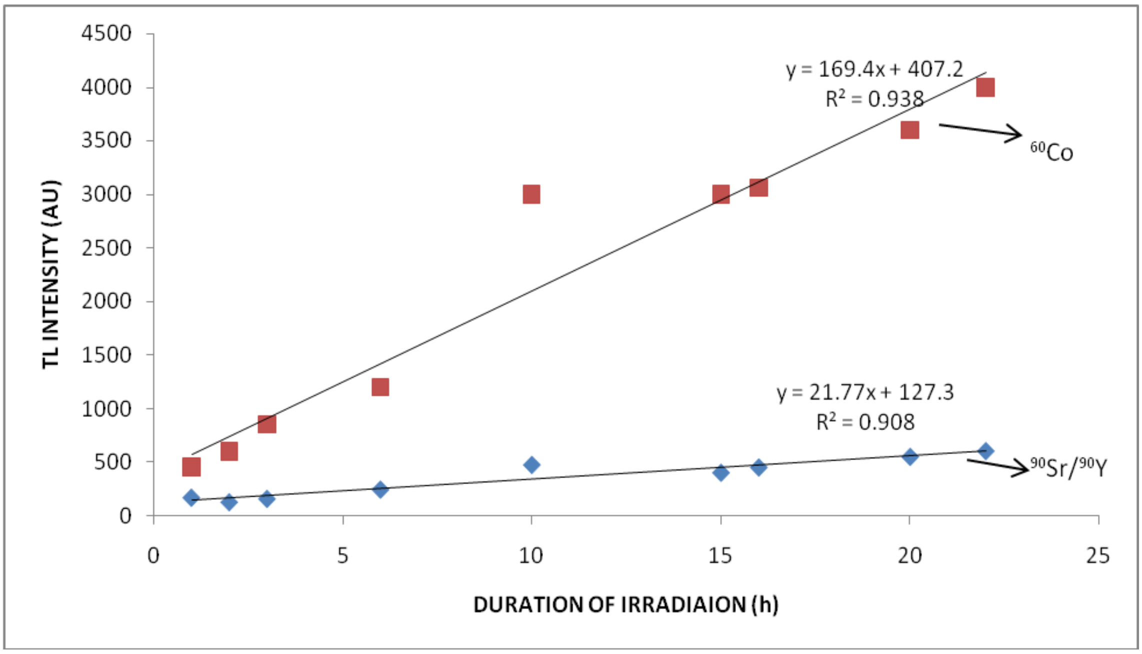

Fig. 5: Dose response of synthetic Fused quartz with ^{60}Co and $^{90}Sr/^{90}Y$ irradiation sources respectively

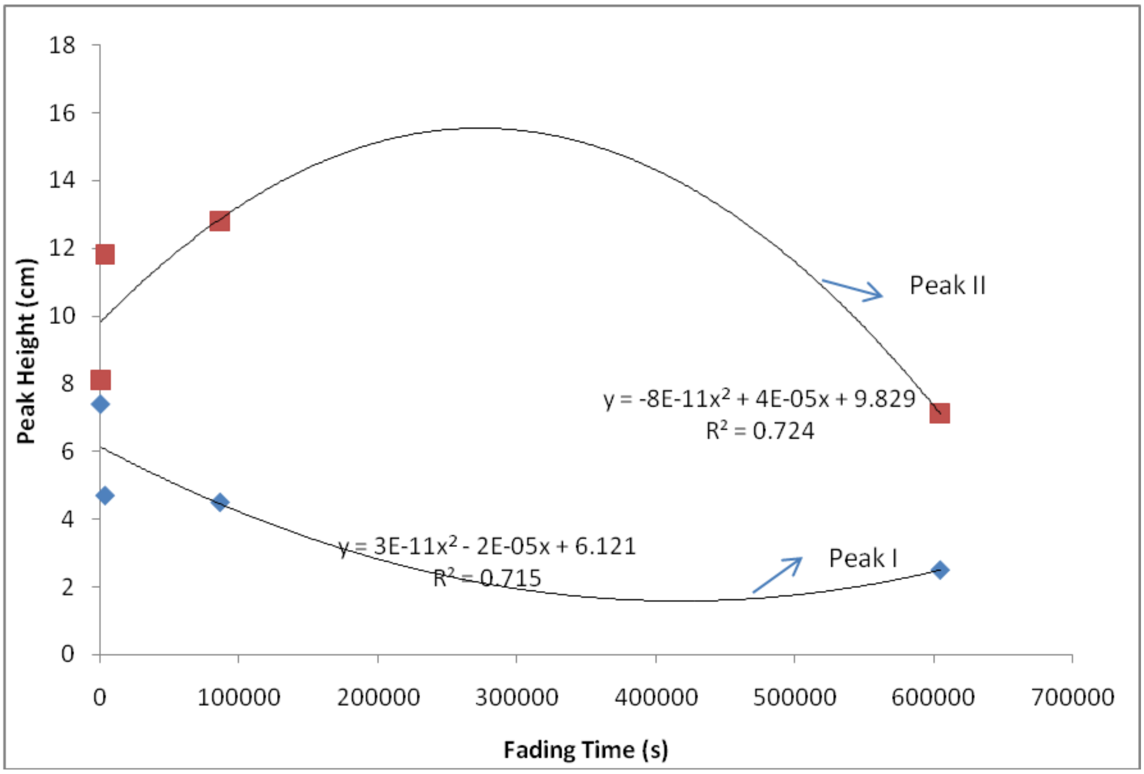

Fig. 6: Fading pattern of synthetic fused quartz with ^{60}Co irradiation source

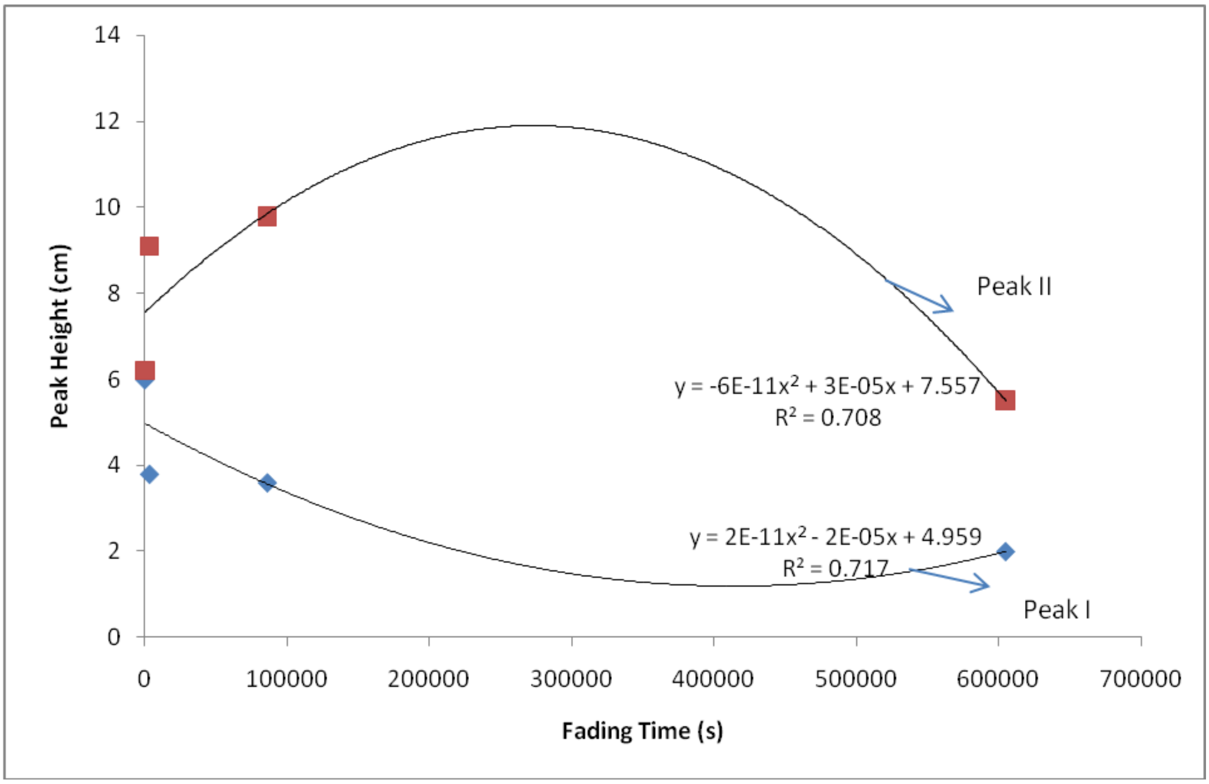

Fig. 7: Fading pattern of synthetic fused quartz with ^{90}Sr/^{90}Y irradiation source

Fading pattern

For the fading study, a set of synthetic fused quartz was irradiated for 1 h with the two irradiation sources use in this investigation.

Fading characteristics of exposed synthetic fused quartz to gamma and beta rays using the ^{60}Co and ^{90}Sr/^{90}Y sources are as given in Figs. 6 and 7. Our data revealed an overall trend that depicts a mechanical tunneling of the low temperature to the higher ones at the few delayed periods. This observation was consistent with the two irradiation sources. This consistency, with repeated readout of this material with the two irradiation sources had made it possible to isolate the 175 °C peak which faded somehow as expected as the dosimetric peak. It became imperative to mention that the fading study was observed for one week owing to fast fading nature of this glass [4]. Although there was a high rate of fading within the first six hours of post irradiation read out. This was followed by slower fading in the next three days. The TL signal stabilizes after one week of post irradiation read out. This is attributable to the presence of shallow traps which are fast decaying with storage time.

4. CONCLUSIONS

We have here described the possibility using an alternative of natural quartz, the synthetic fused quartz as a dosimeter for high and low dose measurements in a mixed field radiation dosimetry.

The well isolated glow shape, the linear dose response and the consistent fading pattern especially those of the 175 °C peak of this phosphor as obtained with both gamma and beta rays suggest the possible usage of this material in environmental monitoring especially in the area of mixed-field radiation dosimetry.

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