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# Effect of visible and ultraviolet light on TL study of topaz glass composites

## Efeito de luz visível e ultravioleta na termoluminescência de compósitos de topázio-vidro

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Topázio é um mineral de ocorrência natural, que apresenta termoluminescência (TL) após exposição a radiação beta e gama. Neste trabalho foram analisadas amostras de topázio coletadas da mina Nyit em Baltistan, região Norte do Paquistão. As amostras, após preparadas na forma de pó, foram misturadas com vidro de janela na proporção de 2:1 em peso para formar compósitos de topázio-vidro. O propósito deste estudo foi analisar as características TL e o efeito da luz visível e da luz ultravioleta (UV) sobre os compósitos após irradiação com fonte de radiação beta. Os compósitos foram irradiados com doses entre 0,1 e 2000 Gy. As emissões TL exibem dois picos entre 100 – 115$^{o}$C (pico 1) e 141 – 163$^{o}$C (pico 2). Com o aumento da dose, a intensidade do pico 2 cresce linearmente, sem qualquer variação na sua posição, dentro da incerteza estatística. Os coeficientes de correlação linear para os picos 1 e 2 foram 0,98 e 0,99, respectivamente. A influência da luz visível e da luz UV sobre a TL das amostras irradiadas com beta revela um acréscimo que pode ser devido à fototransferência de cargas. A reprodutibilidade da resposta TL após cinco ciclos de reutilização dos compósitos mostrou uma incerteza de ± 6%. Pode-se inferir dos resultados que compósitos de vidro com topázio da mina Nyit são viáveis para dosimetria de radiação beta.

Palavras-chaves: Compósitos topázio-vidro; Luz ultravioleta; Curva de emissão; Reprodutibilidade

Topaz, a naturally occurring aluminium fluorosilicate mineral, shows thermoluminescence (TL) after irradiation to beta and gamma rays. Topaz samples were collected from the Nyit mine in the Baltistan region in northern Pakistan and grinded to make powder. The powder of topaz was mixed with that of window glass in ratio of 2:1 of weight to form topaz-glass composite. The purpose of this experimentation was to study the TL characteristics and the effect of visible and ultraviolet (UV) light on composites after irradiation with beta source. The composite was irradiated at 0.1 –2000 Gy. The TL glow curves exhibit two peaks within 100 – 115$^{o}$C (peak 1) and 141 – 163$^{o}$C (peak 2). With the increase of dose, the intensity of peak 2 increased linearly without any change in its positions within the statistical uncertainty. The linear correlation coefficients for the peaks 1 and 2 were 0.98 and 0.99 respectively. The influence of visible and UV lights on the TL emission of beta irradiated composite revealed an increase in the TL intensity that may be due to photo-transference of charge. The reproducibility in TL response after five cycles of reuse of the composite was found to be same within ± 6% statistical uncertainty. It can therefore be inferred that the composite of glass with topaz from Nyit mine is a suitable material for beta dosimetry.

Keywords: Topaz glass composite; Ultraviolet light; Glow curve; Reproducibility

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## 1. INTRODUCTION

The phenomenon of thermoluminescence can be defined as the thermally stimulated emission of light from an insulator or semiconductor subsequent preceding absorption of energy. A worth noting point which can be concluded from this definition, is that there are certain essential requirements of the process such as 1) the material should be insulator or semiconductor as metals do not exhibit any thermoluminescence, 2) there must be a previous absorption of energy, and 3) the emission is caused by heating of the material [1].

Nishita et al. also found natural TL in various minerals and topaz with a chemical formula $Al(F, OH)_2 SiO_4$ is one of those [2]. Souza et al. characterized topaz samples from Santo do Jacinto, Minas Gerais, Brazil and compared the results with that of LiF made TLD [3]. They found that colourless natural Brazilian topaz is a suitable material for gamma dosimetry and the composites of natural colourless topaz crystals with glass can efficiently be used as a TL dosimeter. They used small pieces of topaz crystals to verify the TL characteristics and compare with the conventional LiF dosimeter. Relative intensities and positions of different peaks in the glow curve are affected by the thermal treatment (annealing) of TL material [4]. Many researchers made composites of topaz with other materials and recommended them for personal and environmental dosimetry due to more stability at room temperature [5, 6]. Magalhaes et al. used the topaz–glass composite [6] and investigated the followings: the linear TL response within a large dose range, reduced sensibility to visible light, slow fading of the TL response, and mechanical stability at successive cycles of annealing, irradiation and measurement. Souza et al. suggested that the TL emission of topaz are related to the origin of the sample and consequently to the impurities that can be different from one place to another [7].

Beta radiation may cause harmful effects to the workers and the extremity dosimeters become particularly significant [8]. Various types of thin detectors of highly sensitive TL phosphors, $MgB_4O_7$:Dy; $CaSO_4$:Dy; $Al_2O_3$:C and LiF:Mg,Cu,P have been prepared and tested for beta dosimetry [9]. A little work has been done on beta dosimetry with topaz. Our struggle is to design and develop a TL dosimeter based on natural mineral topaz.

It is difficult to fabricate pellets to use as thermoluminescente dosimeters from the powder of pure topaz by sintering. If the sintering temperature is increased then sensitivity of topaz powder is reduced due to volatilization of metallic impurities which play a significant role in trapping of the charged particles. However, if the pellets are prepared using a mixing glass with topaz as composites then it is possible to reduce the sintering temperature. In this case the TL peaks in the glow curve appear at about 115 and 160$^{o}$C. Therefore, the TL measurements and the thermal annealing can be performed up to 350$^{o}$C to provide the complete spectrum emission and to eliminate the TL emission from topaz before reusing the sample. In addition with that a very little work has been done for topaz glass-composite as far as beta dosimetry is concerned.

The objective of present work was to study the effect of visible and UV light on the TL characteristics of topaz-glass composite irradiated by beta particles. The samples of topaz were collected from Nyit mine in Biltistan region of Pakistan. The TL characteristics of topaz from the understudy mine were also characterized after irradiation with beta particles. It was the first study on topaz glass-composites (in 2:1 weight) as far as the TL dosimetry is concerned. In this report we have also introduced the optimum conditions for the preparation, sintering and TL characterisation of topaz-glass composites.

## 2. MATERIALS AND METHODS

### *Sample management*

Topaz is found at various locations in the northern areas of Pakistan. The samples of topaz were collected from Nyit mine in Baltistan region of Pakistan. The size of topaz crystals varied from 2 to 4 cm. Topaz crystals were cleaned according to the procedure adopted by Lima et al. [10] that consists of 50% water and 50% Aqua Regia ($3HCL+HNO_3$) solution to remove the dust/dirt and particles of other minerals/ores associated with the lumps of topaz. Relatively large size pieces of topaz crystals were cut in to small pieces using Accutom Precision Cut-off machine (Model: Accutom-50, Stucers). These pieces were then converted in to powder of particle size in between 45 to 75 µm. To make the topaz window glass composite, glass was also converted in to powder form of particle size in range of about 25 to 75 µm.

**Preparation of topaz- glass composite pellets**

The powders of topaz and glass (in 2:1 ratio) were mixed thoroughly by ensuring complete homogeneity. One drop of 0.1 g/ml poly vinyl alcohol (PVA) as binder was mixed with the homogenous mixture of the powder [6]. To make the pellets of 3 mm diameter and 1 mm thickness, the mixture was compressed under a hydraulic press by applying pressure of 120 Kgf/cm$^2$.

***Sintering and Annealing***

The pellets of topaz glass-composite were then sintered for one hour in the furnace (EDG-3O-S, Model F-1800, Brazil) at about 1000$^o$C. Whenever required, the annealing of these pellets was carried out for one hour at 400$^o$C in the furnace used for sintering.

***Irradiation***

Fifteen pre-selected pellets of topaz-glass composite were irradiated for various doses with beta calibrator ($^{90}$Sr+$^{90}$Y). All irradiations were performed at room temperature under the same parameters and conditions.

***Exposure to visible and UV light***

To observe the effect of visible and UV light on the TL output at room temperature, five irradiated pellets were exposed to the fluorescent lamp mounted at a distance of about 1 m from the pellets, five were placed in the visible light, and five were wrapped in black paper for about 24 hours. The post irradiation time was also kept constant for the experiment.

***TL study***

For study of the glow curve, the irradiation dose to the pellets was from 10 to 50 Gy, while for study of the dose response the dose was from 0.1 to 2000 Gy. A reader analyzer (Harshaw Model: 3500, USA) was employed to measure of the TL response of topaz-glass composite at 50–350$^o$C. The planchet of TLD Reader was cleaned with alcohol and citric acid to remove the deposited dust particles. The linear heating rate was set at 5$^o$C/s on the TL reader. Glow curves pertaining to different dose levels were studied for the sample of the understudy mine. Mechanical stability was also observed for 30 cycles of annealing, irradiation, and measurement. In all the experiments, each reading was an average of the readings of two pellets.

## 3. RESULTS AND DISCUSSION

***Glow curve***

The glow curve plays a vital role in radiation dosimetry and is defined as the plot of TL intensity versus heating temperature. The glow curve consists of one or more peaks depending upon the formation of trapping levels in band gap. The glow curve describes the behaviour of the trapping levels and might be utilized to fix various reading parameters i.e. temperature, heating rate and time [11, 12-13]. The temperature against the peak is a dominant factor to decide that typical peak should not be vanished at room temperature; also corresponding temperature of the peak should not be so high enough to present the instrumental problem for

TL output measurements. The height of the glow curve represents the number of electrons released at particular temperature [11].

Two peaks in the glow curve of topaz-glass composite of the understudy mine were observed at temperature range 100 – 115 °C (peak 1) and 141 – 163 °C (peak 2) after irradiation to beta source from 0.1 to 2000 Gy dose. The two peaks correspond to two trapping levels of topaz-glass composite. With increase in irradiation dose, the intensity of peaks increased with a slight change in peak position that may be the statistical variations. The position of the peaks with increasing the dose levels were presented in the Table. 1.

*Table 1. Centre line temperatures of Peak 1 and 2 of the topaz glass composite irradiated with Beta source for various dose levels.*

| ***Sr. No.*** | ***Dose (Gy)*** | ***Temperature (°C)*** | |
|---|---|---|---|
| | | ***Peak 1*** | ***Peak 2*** |
| 1 | 0.1 | 105 | 162 |
| 2 | 1 | 106 | 163 |
| 3 | 10 | 115 | 163 |
| 4 | 20 | 115 | 162 |
| 5 | 30 | 112 | 162 |
| 6 | 40 | 114 | 160 |
| 7 | 50 | 113 | 155 |
| 8 | 100 | 114 | 159 |
| 9 | 500 | 113 | 158 |
| 10 | 800 | 100 | 141 |
| 11 | 1000 | 101 | 156 |
| 12 | 1200 | 111 | 153 |
| 13 | 1500 | 102 | 142 |
| 14 | 1800 | 115 | 163 |
| 15 | 2000 | 111 | 152 |

The glow curves of the composite for beta irradiation dose of 10, 30 and 50 Gy are shown in Fig. 1 while glow curves for the dose of 1500 Gy and 2000 Gy can be observed in Fig.2. The occurrence of peak 2 in the glow curve was in agreement that studied by Samuel et al. for natural Brazilian topaz [14]. Magalhaes et al. also studied the TL characteristics of topaz-glass composite in 1:1 ratio and found the TL peak in the glow at 200 °C after irradiation with X-rays for the dose of 5 Gy [6]. It means that trapping levels of natural topaz and that of the composite may or may not be the same. Therefore glow curve analysis of topaz of each origin and it composites is essential before its use for dosimetric applications.

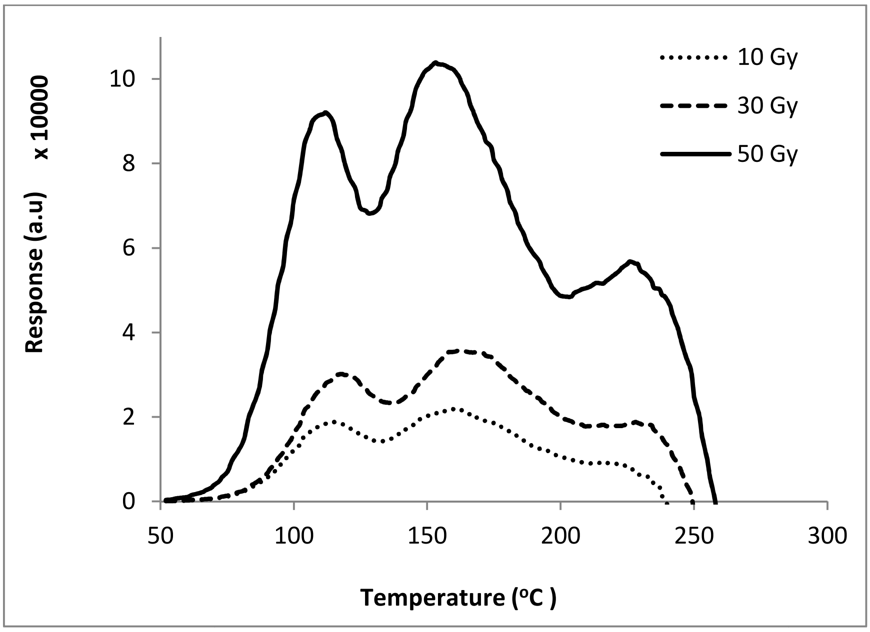


*Figure. 1 Glow curve of topaz: glass composite in ratio 2:1, sintered at 1000 °C for one hour, irradiated for the various doses with Beta irradiator and TL read out with Harshaw (TLD-3500) at the heating rate of 5 °C/s.*

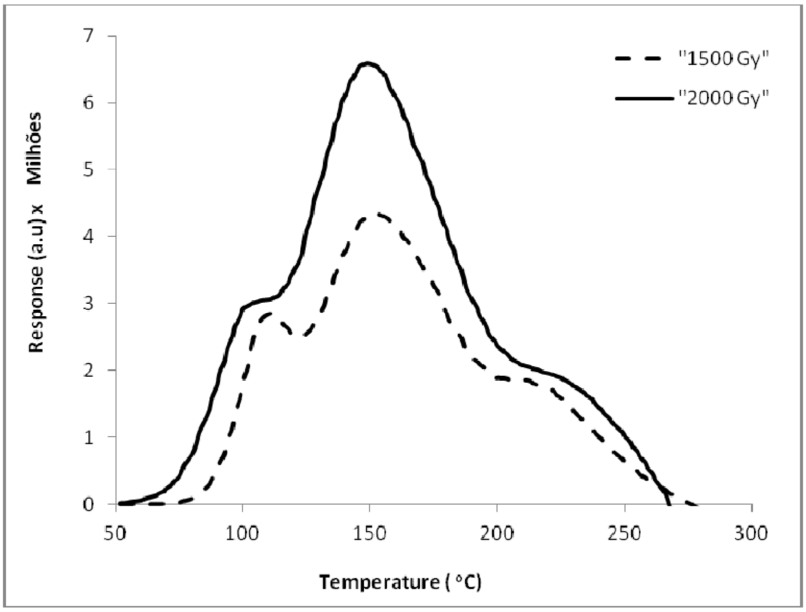


*Figure. 2 Glow curve of topaz: glass composite in ratio 2:1, sintered at 1000 °C for one hour, irradiated for 1500 and 2000 Gy doses with Beta irradiator and TL read out with Harshaw (TLD-3500) at the heating rate of 5 °C/s.*

There is stability of peak 2 and it rose linearly with dose that may be used for dosimetric application. The temperature of the peak 2 is not too high that may cause the instrumental problem, in addition not too low that may be vanished at room temperature. So it is convenient to say that topaz glass composites may be used for high radiation field such as radiotherapy and sterilization beams for dosimetric application.

***Dose response***

Dose response is the variation in the TL intensity with dose, desired to be linear for the TL material to be used as dosimeter. The term linearity means that the response verses dose curve should make an angle of 45 $^o$ with the positive X-axis on the log-log scale [12]. The linear increase in intensities of the peaks 1 and 2 versus dose are presented in Figs. 3 and 4 respectively. The linear correlation coefficient for the peak 1 was 0.98 and that for the peak 2 was 0.99.

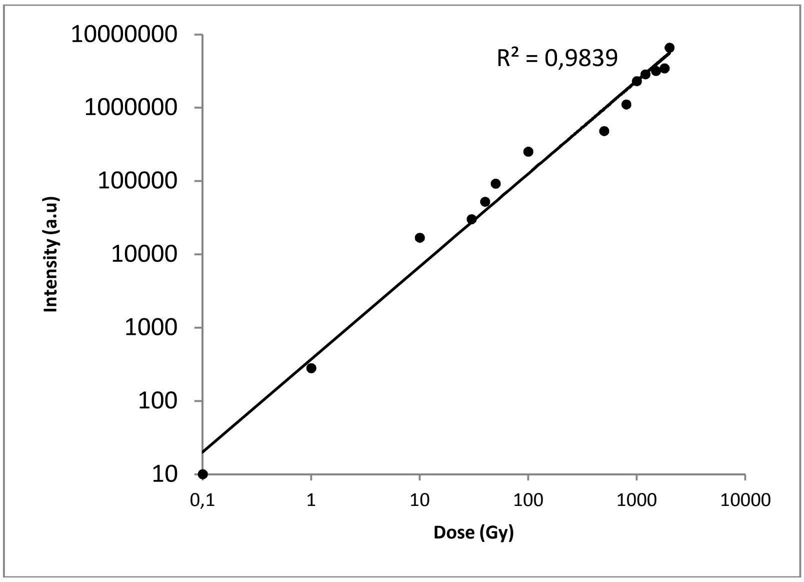


*Figure. 3. Intensity of Peak 1 of topaz composites irradiated for the various doses with Beta irradiator and TL read out with Harshaw (TLD-3500) at the heating rate 5 $^o$C/s.*

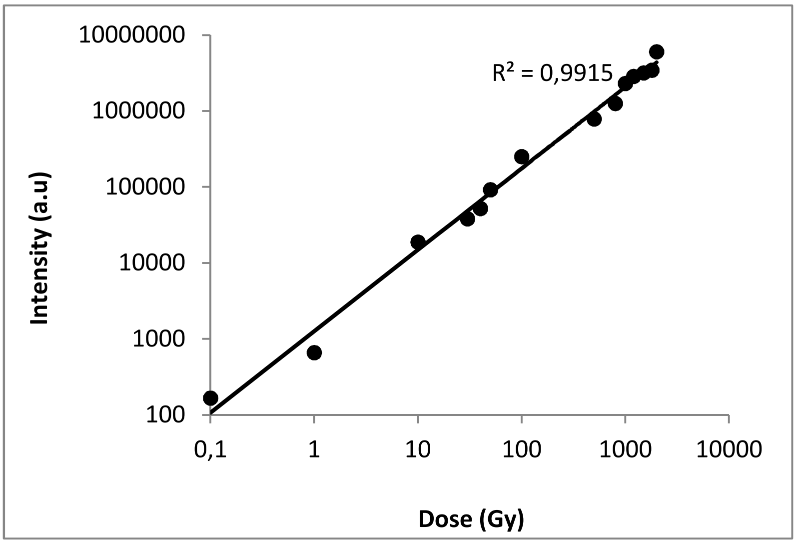


*Figure. 4. Intensity of Peak 2 of topaz composites irradiated for the various doses with Beta irradiator and TL read out with Harshaw (TLD-3500) at the heating rate 5 $^o$C/s.*

### *Effect of visible and UV light*

The glow curves of the composite irradiated at 15 Gy dose, placed in visible and UV light and wrapped in dark paper are presented in Fig. 5. The samples placed in visible and UV light have higher intensity in the glow curve as compared to the samples which were wrapped in black paper. Similarly, the samples exposed to UV light have higher intensities in the glow curve than the samples which were exposed to visible light. The peak 1 is almost diminished under the effect of visible light. The whole experiment was repeated two times and almost similar results were obtained. The effect of optical stimulation on the performance of the topaz–glass composites was also studied by Magalhaes et al. [6]. They found that intensities of the TL peaks were different for illuminated and non-illuminated samples. They also investigated that intensities of one peak in the glow curve decreased while the intensity of second peak increased for the illuminated samples, indicating that the optical stimulation with visible light is able to promote the photo-transference between the traps responsible for these peaks.  It can be concluded that it is necessary to protect the topaz–glass composites dosimeter from the visible and UV light.

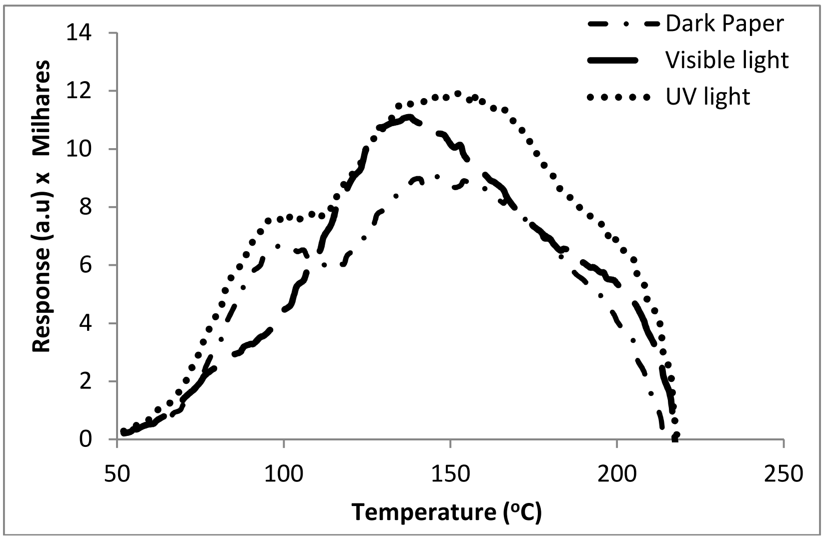


*Figure. 5.  Effect of visible and UV light on the topaz glass composite irradiated with dose about 15 Gy with Beta irradiator and TL read out with Harshaw (TLD-3500) at the heating rate of 5°C/s under different environmental condition.*

### *Reproducibility*

According to IUPAC, Compendium of Chemical Terminology the term reproducibility can be defined as “The closeness of agreement between independent results obtained with the same method on identical test material but under different conditions (different operators, different apparatus, different laboratories and/or after different intervals of time)” or “the value below which the absolute difference between two single test results on identical material obtained under the above conditions, may be expected to lie with a specified probability” [15]. The reproducibility of the TL material is desired to be identical and lies within the acceptable range to be used as dosimeter [1].

The reproducibility of the topaz-glass composite was checked for its reuse after a cycle of annealing, irradiation and measurement. The composite pellets irradiated with 10 Gy beta dose were annealed for one hour. The TL intensities of peaks 1 and 2 after every cycle were noted. Under same experimental parameters and configurations, a set of five chips was repeated for 30 times. An average of the readings of five chips was considered as one reading for a particular cycle. A fluctuation of about ± 6% was observed, however this value decreased at higher dose values. Magalhaes et al. found the TL intensity of a maximum deviation of 6.9% in a single cycle [6].

***Mechanical stability***

About 50 pellets of topaz-glass composite of 3 mm diameter and 1 mm thickness were prepared to accomplish different experiments to study the TL characteristics of topaz of study mine. In all these experiments, the chips were annealed, irradiated and measured numerous times. The experiments of different nature need to be recurrent many times. The pellets of the composite remained intact during mechanical handling, therefore mechanical stability of topaz as a TLD was insured for the study samples. This property also favours the topaz glass composite for its use as a TLD.

## 4. CONCLUSIONS

The pellets of 3 mm diameter and 1 mm thickness were prepared from the mixture of topaz and glass powder. The TL study such as glow curve, dose response, reproducibility and mechanical stability were studied. The effect of visible and UV light on the peak position of glow curve and response of previously irradiated samples with beta particles was also studied. The peak in the glow curve of topaz-glass composite is at that temperature that cannot be vanished at room temperature and not at so high that may cause the instrumental problem. Topaz-glass composite dose response of peak 2 is linear between the dose range of 0.1- 2000 Gy so these composites can efficiently be used for beta dosimetery in a high radiation field. Topaz glass composites showed a good reproducibility within the range of about ± 6% of fifth cycle with respect to first cycle. These samples also showed mechanically stability and remained intact over the whole experimentations of irradiation, annealing and measurements. It is appropriate to say that topaz of the understudy mine can efficiently be used for dosimetric applications.

## 5. ACKNOWLEDGEMENTS

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