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# The Effect of Different Physical Treatment and Stimulation Temperature on OSL Decay Curve of Synthetic Quartz Material

**T. B. Akhani[1], Y. D. Kale[2], and Y. H. Gandhi[3]**

[1]Parul Institute of Applied Sciences, Parul University, P O Limda, Vadodara, Gujrat, India
[2]Applied Sciences and Humanities Department, Parul Institute of Technology, Parul University, P O Limda, Vadodara. Gujrat, India
[3]Applied Physics Department, Faculty of Engineering and Technology, M. S. University of Baroda, Vadodara Gujarat, India

Correspondence should be addressed to T. B. Akhani; trilokkumar.akhani@paruluniversity.ac.in



**ABSTRACT**: Researchers reported, in natural quartz probability of re-trapping of electrons by shallow TL traps gets reduced for Optically Stimulated Luminescence (OSL) at around 160 0C and usual shape of OSL decay curve is obtained. Under influence of critical physical condition followed by optical stimulation at room temperature in synthetic quartz material, identical OSL outcomes are observed. Below these critical physical conditions to the material neither usual shape of OSL decay curve is obtained nor does it give significant OSL signals. In current investigations, the consequence of different physical treatment on OSL decay curve of synthetic quartz material is studied. As an OSL outcome, the variations in shape of OSL decay curve as well as OSL strength over 0 to 100 seconds of stimulation time are discussed. Changes in OSL outcomes are responsible to strength of physical treatment to the sample and stimulation temperature followed by growth of favourable new centres. The unusual shape of OSL decay curve suggests the re trapping of optically unconfined electrons still occurred in traps rather than shallow TL traps corresponding to 110oC glow peak. The results are elaborated by resolving components of complex shapes of OSL decay curve and recorded TL glow curves before and after OSL for identical physical conditions to the sample.

**KEYWORDS**: Annealing Treatment, Beta Dose, Elevated Temperature, Optically Stimulated Luminescence (OSL), Synthetic Quartz, Stimulation Temperature.

## I. INTRODUCTION

The optically animated glow (OSL) is caused by charge recombination from metastable energy levels inside a gem that has been optically set free. The number of people living in metastable states is a result of the material's light, therefore the OSL force is proportional to the amount of radiation consumed [1]–[4]. As the metastable charge is depleted during stimulation light exposure, the OSL signal is found to fall to a low level. As illustrated in Figure 1, the depleted electrons from the metastable state take the normal route through the conduction band to recombine with a hole at the recombination center, which shows typical OSL decay. Figure 2 depicts the typical form of OSL decay as an exponential decline curve from maximum OSL intensity as a function of stimulation time (t).

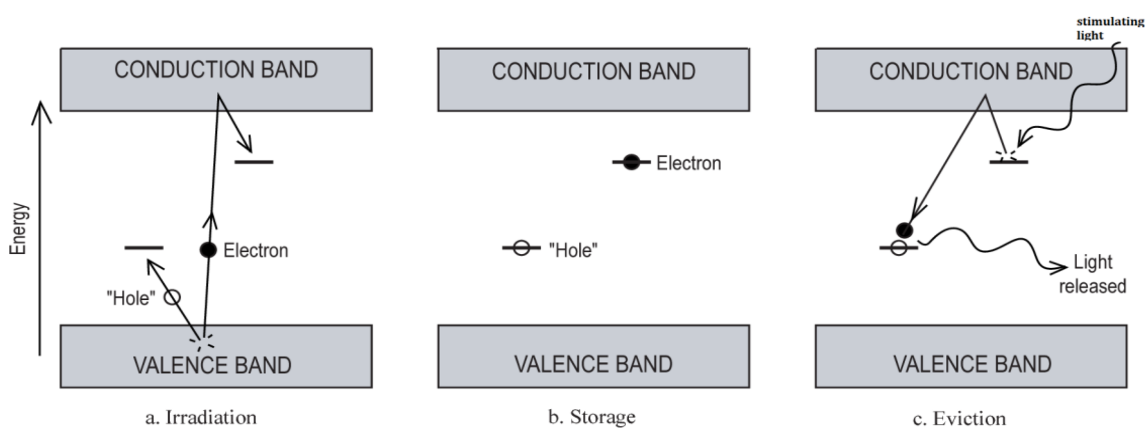


Figure 1: Electrons are trapped in a crystal flaw. a. Irradiation: when a crystal is exposed to radiation, it ionizes

b. Electron storage: an electron is stored and a positively charged "hole" is left behind. c. Eviction: an electron is freed from its trap by shining light of the right wavelength onto the sample. When a hole recombines with a molecule, a measured quantity of light is released.

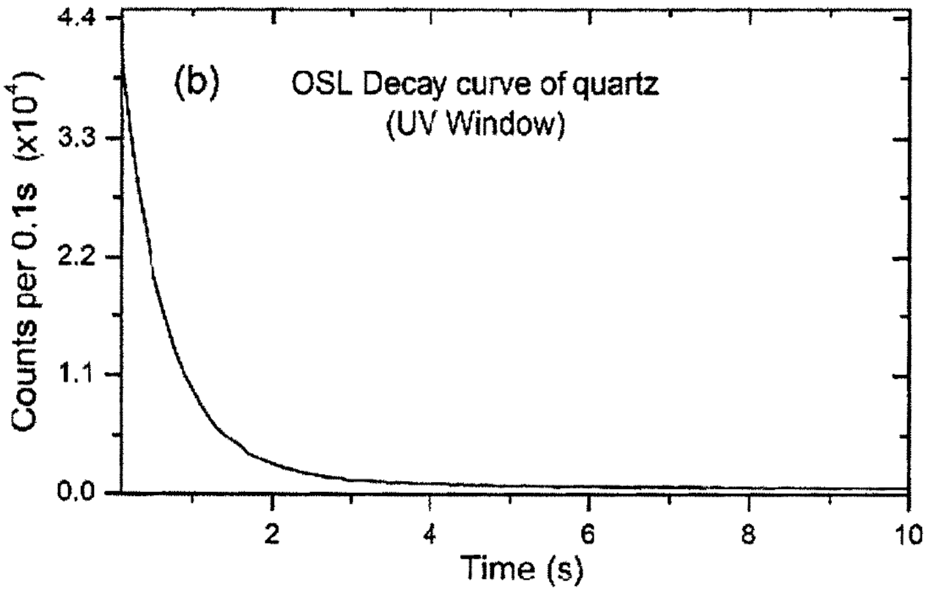


Figure 2: Illustrates the OSL decay curve recorded of synthetic quartz.

Researchers reported that shape of OSL decay curve for natural quartz material is influenced by physical treatment to the sample prior to OSL measurement and experimental condition. As OSL rot bends have recorded close to room temperature, the example showed surprising state of OSL rot bend with more vulnerable OSL result [6]–[9]. In some strange shape, OSL force saw as dramatically developing and in rest it is directly becoming followed by regular remarkable rot. Explanation for it is presumed that re-catching of optically delivered electrons by shallow TL traps comparing to 110oC shine top over their possible recombination at glow focuses. The place of this standard TL sparkle top differs from 89oC to 150oC under impact of state of being to the quartz test. Hence researchers [10] In some strange shape, OSL force saw as dramatically developing and in rest it is directly becoming followed by regular remarkable rot. Explanation for it is presumed that re-catching of optically delivered electrons by shallow TL traps comparing to 110oC shine top over their possible recombination at glow focuses. The place of this standard TL sparkle top differs from 89oC to 150oC under impact of state of being to the quartz test. Kale et al. [4]have reported that usual shape of OSL decay followed better OSL outcomes is possible near room temperature stimulation under influence of critical physical conditions in synthetic quartz material. Under influence of these combine effects (physical treatment and optical stimulation temperature), the complex shapes of OSL decay curve with changes in their OSL sensitivity are observed. As a complex shapes of OSL decay curve, two shapes of OSL decay curves are considered as an unusual decay in which (i) within zero to ~25seconds of stimulation time, the OSL intensity increases by way of exponential growth and reaches at maximum OSL counts thereafter it exhibits decay with weaker OSL signal (ii) within 0 to 0.4seconds of stimulation time, the OSL intensity increases by way of linear growth and reaches at maximum OSL counts thereafter it exhibits decay with better OSL (iii) at zero second of stimulation time, the OSL intensity is maximum thereafter it exhibits decay with rise in stimulation time and gives best OSL signal.These outcomes are discussed by support of attempt to resolve the components for complex shapes of OSL decay curve and recorded TL glow curves before and after OSL.

(AQ) test. This process was repeated for 600oC and 1000oC annealing treatment at identical duration[4], [9], [11], [12].

The 5mg of sample was collected and sprayed in the form of layer over the sample disc. By these method, one disc was prepared as unannealed sample and six discs were prepared for each annealed sample. These sample discs were arranged in RISO system which has in built facilities of Sr-90 beta irradiation source, stimulation source from visible part of spectrum and three detection filters [Hoya U-340 (Quartz OSL is often detected using the Hoya U-340 filter), Schott BG 39 and Corning 7-59or BG3 filter has been replaced by BG3).

Prior to record OSL decay curves; each annealed sample was exposed by 2.52Gy, 25.2Gy, 5.04Gy, 151.2Gy, 75.6Gy, 302.4Gy of beta radiations with the dose rates of 0.084Gy/second. The physically treated samples were optically stimulated at 160oC elevated temperature for 100 seconds of stimulation by bluish-green light (470nm). The OSL signals are normalized by weight(5mg) and results are elaborated by (i) TL glow curves are recorded over 25oC to 573oC measurement temperature under heating rate of

5oC/second for unannealed and annealed sample before optical stimulation (ii) the OSL components which have been resolved by ORIGIN8 software and (iii) TL glow curves are recorded over 25oC to 573oC measurement temperature under heating rate of 5oC/second for annealed sample after optical stimulation.

## II. DISCUSSION

Literatures have reported that the popular of TL glow curves for dissimilar categories of quartz have shown a cluster of points at temperatures of 80oC, 100-110oC, 130oC, 180oC, 200-210oC, 230oC, 310oC and 350oC. Albeit, countless examinations of the TL properties of quartz have been played out, the TL tops at 100-110oC, 200-210oC and 350oC were particularly all around contemplated. Smith B W et al [15] have reported that the OSL studies have a link between OSL and the optically induced decay of the 305oC-325oC TL peak. Subsequently, in present examinations, the progressions in state of OSL rot bend and OSL power under impact of consolidate impacts might propose the relationship among's OSL and TL shine bend design. Therefore, it necessary to study the TL glow peak pattern under different physical condition which will be identical in OSL study of synthetic quartz sample.

Thermo luminescence study of unannealed and annealed synthetic quartz:

The TL glow curves are recorded from 25oC-573oC for unannealed sample irradiated by 5.04Gy beta dose. It exhibits three separate glow peaks at ~110oC, 220oC and 332oC with TL intensities of 1297counts, 61counts and 101counts respectively. The TL sensitivity and position of these TL glow peaks are examined under influence of 600oC and 1000oC annealing temperature of 1hour duration followed by identical beta dose. The position of 110oC TL is varied up to 122oC with rise in annealing temperature followed by significantly enhancement of TL intensity by 38667counts in 600oC and 202620counts in 1000oC annealed samples. It suggests that the annealing treatment sensitized to 110oC TL glow peak by 30 times more for 600oC and 156 times more for 1000oC annealed samples compared to unannealed sample. Additionally, the 350oC TL glow peak is developed in 600oC annealed sample and 218oC, 300oC and 370oC TL glow peaks are developed in 1000oC annealed sample. It suggests the position of 332oC TL glow peak varies from 300oC to 350oC with rise in annealing temperature and the 1000oC annealing treatment regenerates~220oC TL glow peak and developed 375oC TL glow peaks as shown in Figure 3.

For present works, the engineered quartz gem was gathered from Center for Glass and Ceramic Research Institute Jadhavpur, Kolkata, India. The insights concerning gem development procedure and trial states of this gem were portrayed somewhere else Using agate mortar and pestle, the fine powder of precious stone was ready with grain size of 63-53µm through standard sifters. The fine powder tests were gathered in four unique cauldrons. Among of them, one crucible of sample was kept at room temperature; it was known as “unannealed” sample and other three crucibles of Experimental Details

sample were prepared for annealing quenched treatment through muffle furnace (temperature range up to 1200oC with ± 1oC accuracy). The sample was held in muffle furnace at 400oC for 1hour duration. After finishing of toughening span at wanted temperature, the example was brought at room temperature for extinguishing process and henceforth this example was named as "strengthened extinguished"

shave been made to resolve the components of OSL decay curve under identical conditions it may establish the correlation between OSL and suggested TL glow peak in present material. For these works, the batches of unannealed, 400oC, 600oC and 1000oC annealed sample of 1 hour duration irradiated by 2.52Gy, 25.2Gy, 5.04Gy, 75.6Gy, 151.2Gy as well as 302.6Gy beta doses are prepared.

The un-annealed samples exhibition unusual shape of OSL deterioration curve in which OSL intensity reaches at maximum counts by way of exponential growth pattern within zero to ~22 seconds of stimulation time thereafter it exhibits slower OSL decay by further rise in stimulation time. Also, the weaker strength of OSL counts is observed at each beta irradiation. It may suggest that the concentration of electron traps increases with beta dose but during stimulation at 160oC temperature optically released may re-trapped by higher temperature TL traps above 160oC which are deep or thermally disconnected traps (Figure 4).

although thermal quenching if present may cause decrease in the luminescence (TL) efficiency effect TL process but the traps those are optically sensitive are participated in OSL process. Further, the optical sensitivity of the individual TL peaks or the traps participating in the process is to studies the effects of optical bleaching at given wavelength on individual TL glow curves and if any optical bleaching/fading is observed, it only indicates the fact that a given TL peak may participate in the OSL process for a given optical wavelength. In view of these, for present sample, the wide contribution of TL glow peaks, the changes in their peak position and TL sensitivity are influenced by physical treatments to the sample may affect on OSL process. In any case, the OSL rot bends are recorded at 160oC temperature for unannealed and strengthened manufactured quartz material followed by beta portions. The influence of combine effects on shape of decay curve and OSL sensitivity are studied and compared for both samples. Also, the attempt

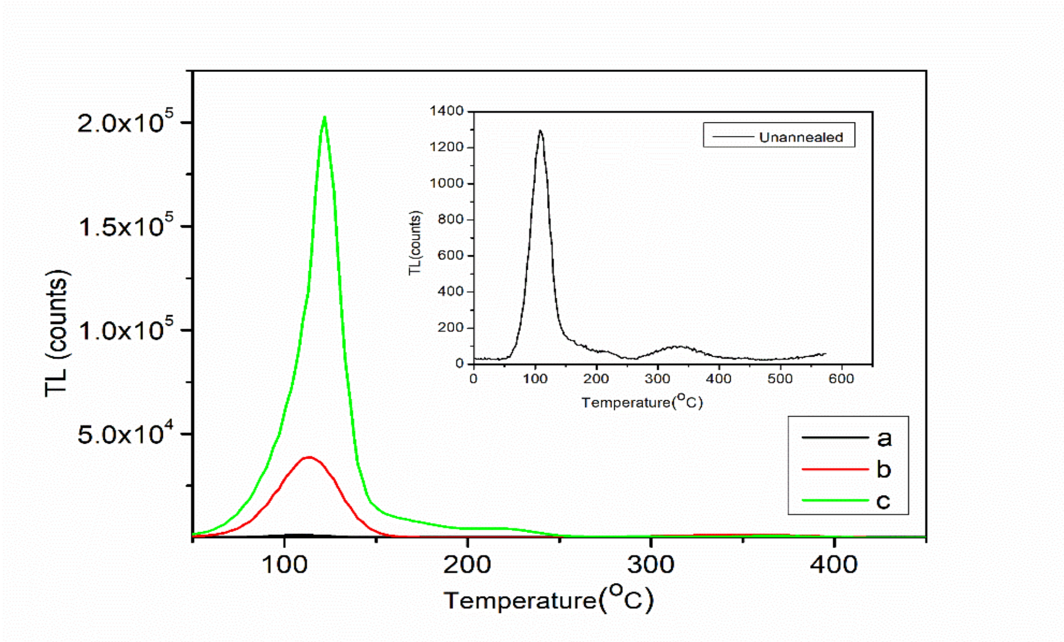


Figure 3: TL glow curves of unannealed and annealed sampled irradiated by 5.04Gy

(a)Un annealed (b) 600oC annealed (c) 1000oC annealed

David et al suggested that [16] the substantial increase of the sensitivity by firing to temperatures between 500oC and 1000oC (with no prior irradiation). They point out that the originally alpha quartz changes at 573oC to beta quartz and at 870oC to tridymite. Chen et al [17]suggested that the annealing of the synthetic quartz removes the competitors which results in an increase in the sensitivity. The suddenly enhancement in TL sensitivity of 1000oC annealed synthetic quartz may responsible to second phase transition effect and minimized the competing electrons traps in quartz material.

OSL study at elevated temperature for unannealed and annealed synthetic quartz:

Researchers [18]reported that all TL the peaks need/may not exhibit OSL but, all the OSL sensitive traps exhibit TL;

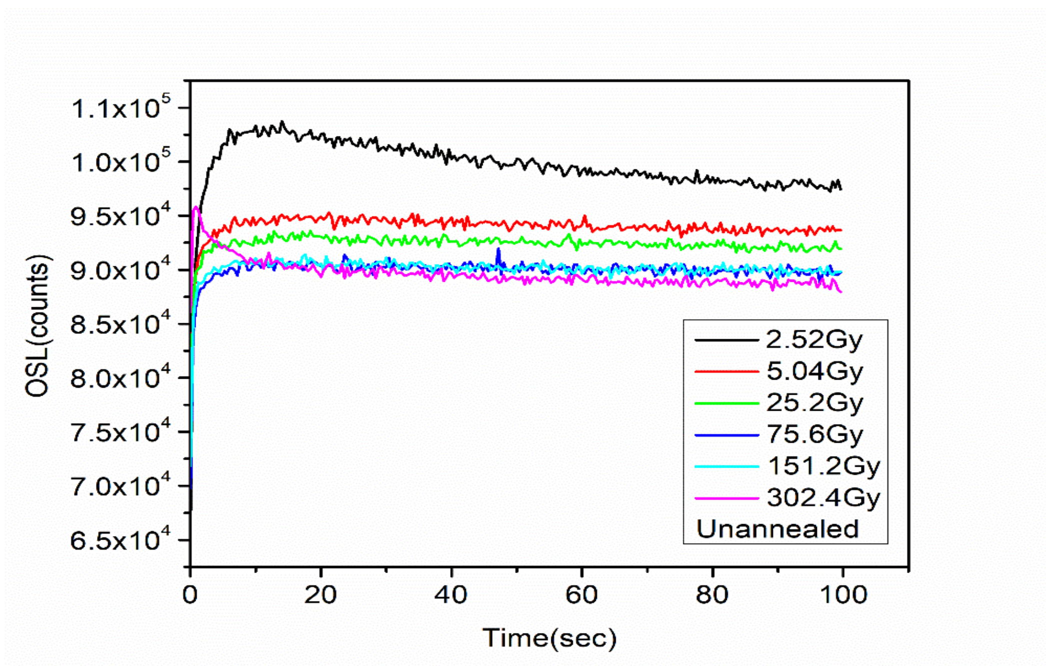


Figure 4: OSL decay at 160oC for unannealed sample irradiated by

(a) 2.52Gy (b) 5.04Gy (c) 25.2Gy (d) 75.6Gy (e) 151.2Gy (f) 302.4Gy

The influence of annealing treatment followed by beta doses and stimulation temperature on these patterns of OSL decay curves are studied. The 400oC annealed sample irradiated by 5.04Gy beta dose exhibits unusual shape of OSL decay curve in which, within zero to ~22seconds of stimulation time, the OSL intensity increases by way of exponential growth and reaches at maximum OSL of 16530.8counts there after it exhibits decay with weaker OSL signal. Above 5.04Gy of beta radiations, the OSL intensity reaches at maximum within 0 to 0.4seconds of stimulation time by way of linear growth thereafter it exhibits decay. The little bit growth in OSL intensity is observed from 17248counts to 25805counts with rise in beta doses above 5.04Gy. Figure 5 It may suggest that 400oC annealing treatment followed by higher irradiations above 5.04Gy causesmore electron traps but these traps are not much sensitized by present annealing treatment and weaker OSL outcomes may be due to major re-trapping of electrons during optical stimulation.

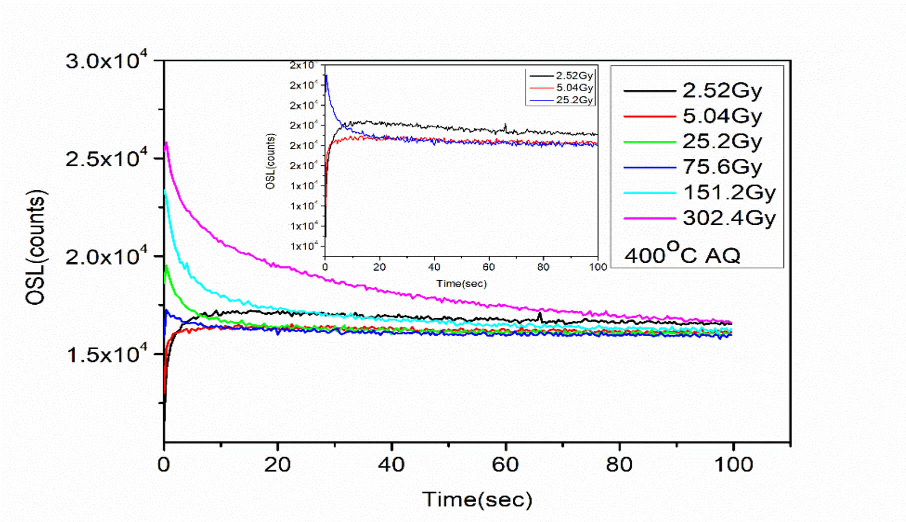


Figure 5: OSL decay curves at 160oC for 400oC annealed sample irradiated by

(a) 2.52Gy (b) 5.04Gy (c) 25.2Gy (d) 75.6Gy (e) 151.2Gy (f) 302.4Gy.

The substantial changes in shape of OSL decay curve followed by OSL sensitivity are observed in 600oC annealed sample. The pattern of OSL decay in which the OSL intensity increases by way of exponential growth and reaches at maximum OSL for few seconds of stimulation time thereafter it exhibits decay with weaker OSL signal is observed below 25.2Gy beta doses. At 25.2Gy beta doses, the pattern of OSL decay is changed in which the OSL intensity reaches at maximum within 0 to 0.4seconds of stimulation time by way of linear growth thereafter it exhibits decay. Beyond 25.2Gy beta doses, the decay is started from maximum OSL intensity with initial stimulation time followed by significant growth in OSL intensity from 18868counts to 137140 counts as shown in Figure 6.

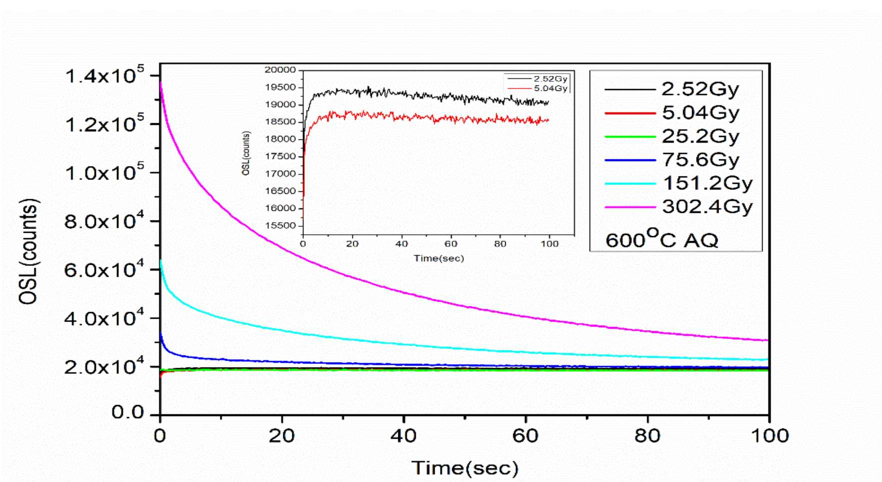


Figure 6: OSL decay curves at 160oC for 600oC annealed sample irradiated by

2.52Gy (b) 5.04Gy (c) 25.2Gy (d) 75.6Gy (e) 151.2Gy (f) 302.4Gy.

The significant usual shapes of OSL decay curve are appeared in the 1000oC annealed sample followed by beta doses. Also, the OSL intensity significantly increased from 26608counts to 1278704counts for each exposure. It is reported that higher annealing treatment may reduce re-trapping of electrons by minimizing of competitors. It is sensitized to the material which shows significant OSL intensity compared to unannealed and lower annealed samples. Also, the 1000oC annealing treatment, the second phase transformation in quartz may responsible to the growth in OSL intensity (Figure 7).

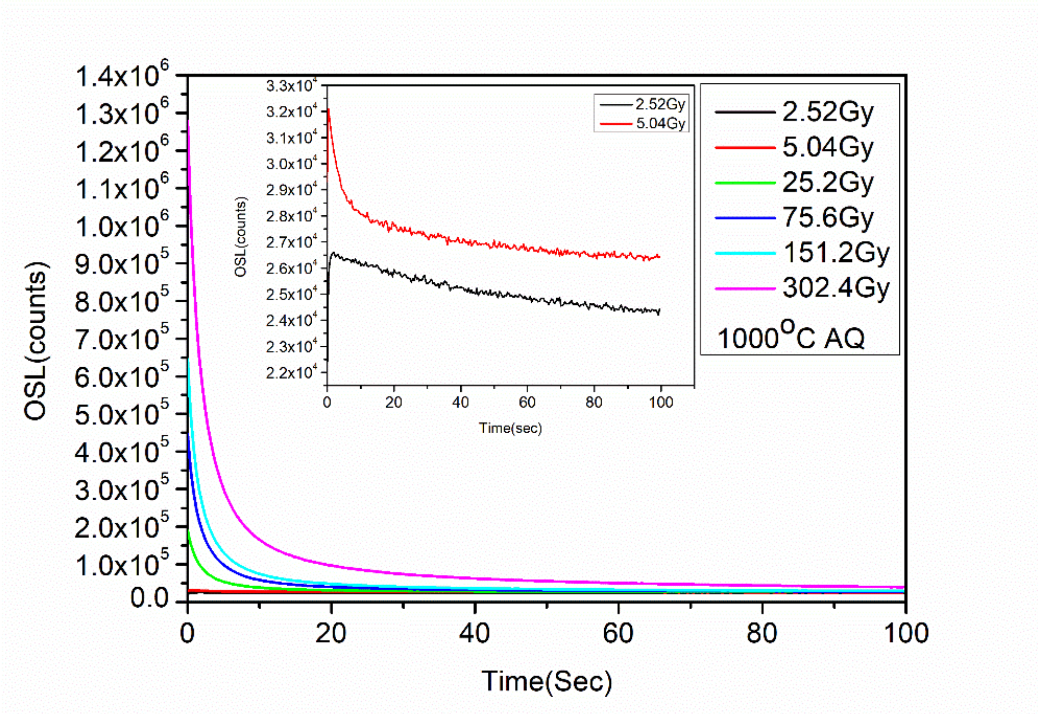


Figure 7: OSL decay curves at 160oC for 1000oC annealed sample irradiated by

2.52Gy (b) 5.04Gy (c) 25.2Gy (d) 75.6Gy (e) 151.2Gy (f) 302.4Gy.

OSL de-convolution study for usual and unusual shape of decay:

As an unusual shape of OSL decay curve, the OSL signal increases to reach at maximum either by way of exponential or linear growth of OSL signal for initial stimulation time thereafter it exhibits decay. These complex pattern of OSL decay curve have been divide in two parts for convolution by suitable fit equations. The portion of exponential growth of OSL intensity is fitted by equation$y = A1\left(1 - \exp\left(\frac{-x}{t_1}\right)\right) + A2\left(1 - \exp\left(\frac{-x}{t_1}\right)\right) + y_0$where; $y$ is OSL counts, $x$ is time, $A1$, $A2$, and $A3$ are amplitudes,$t_1$ and $t_2$ are growth factors, and $y_0$ is offsetand the decay portion of OSL intensity is fitted by equation

$y = A1\exp\left(\frac{-x}{t_1}\right) + A2\exp\left(\frac{-x}{t_2}\right) + A3\exp\left(\frac{-x}{t_3}\right) + y_0$where, $\lambda = \frac{1}{t_n}$ ,$n = 1,2,3..$is decay constantof each component or free electron recombination lifetime ($t_n$) for each trap.

The exponential growth pattern of OSL curve in 400oC annealed sample irradiated by below 5.04Gy beta doses shows two growth components over 0 to ~22seconds of stimulation time. Among of them, the intensity of first component grows very fast and reached at maximum OSL counts within 0.4seconds thereafter it has saturated for further stimulation time. Although, the intensity of second component grows very slower and it takes about ~22seconds of stimulation time to reach at maximum OSL counts. Also, the contribution of fast growth component is more than slower growth component (Figure 8 A).

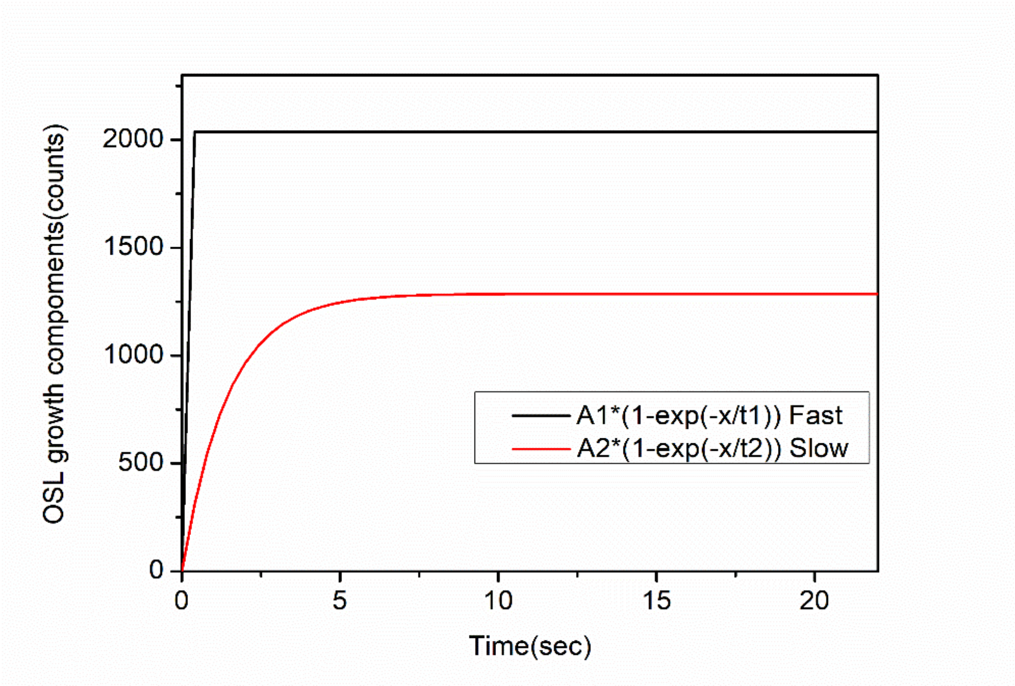


Figure 8 A: Fast and Slow OSL growth components within 0 to ~22seconds of stimulation time in 400oC annealed sample irradiated by 5.04Gy

The decay pattern of identical OSL curve exhibits the contribution of single component with poor decay constant over ~22seconds of stimulation time as shown in Figure 8 B.

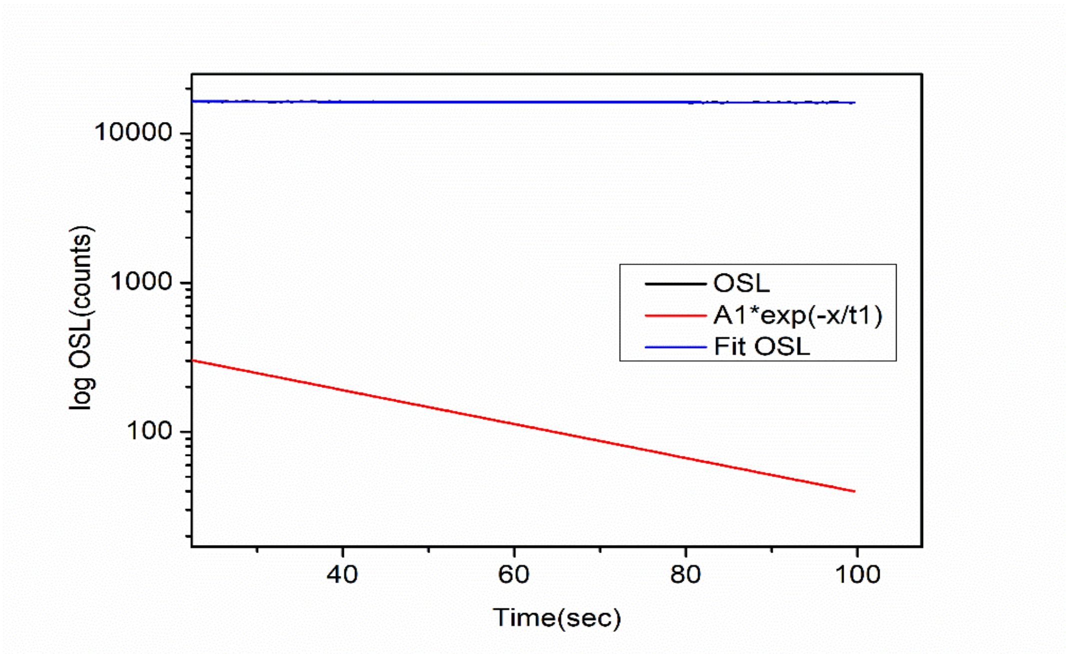


Figure 8 B: Single OSL component at 160oC for ~22-100seconds of stimulation time in 400oC annealed sample of 5.04Gy

The identical sample irradiated by beta doses beyond 5.04Gy exhibits linear growth pattern in OSL curve during 0 to 0.4 seconds of initial stimulation time thereafter it exhibits decay. The initial part of OSL decay curve is fitted by linear fit equation $y = bx + a$ where, $b$ is slope, $a$ is an intercept along intensity axis. It is observed that, as beta dose increases, the magnitude of intercept reduces by increasing the slope line. Beyond 0.4 seconds of stimulation time, the components have been resolved by major contribution of slow component than fast and medium components of OSL decay curve (Figure 8 C).

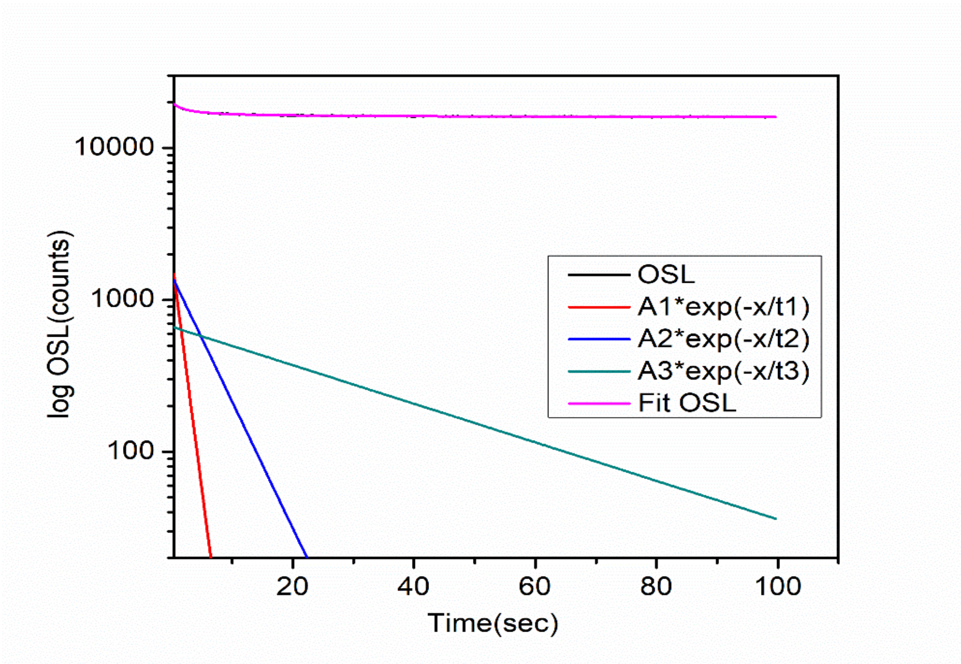


Figure 8C: Multi component of OSL for 0.4-100seconds of stimulation in 400oC annealed sample of 25.2Gy.

The contribution of fast growth component increases with beta doses below 25.2Gy in 600oC annealed sample. Beyond 25.2Gy beta doses, the major contribution of slow component of OSL decay is continued but it increases with beta doses as shown in Figure 9.

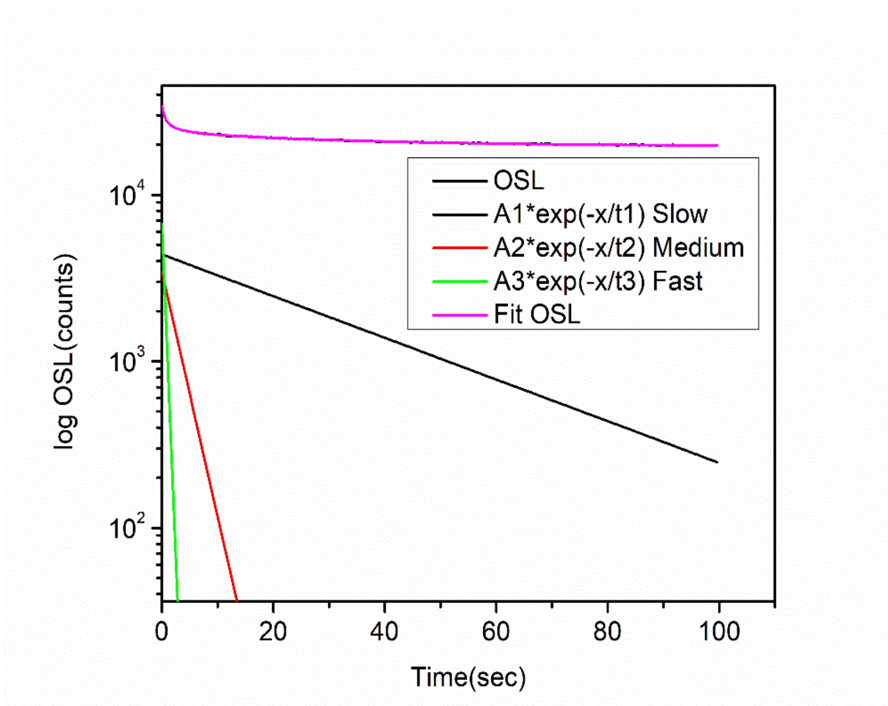


Figure 9: Multi component of OSL for 100seconds of stimulation in 600oC annealed sample of 75.6Gy

The 1000oC annealed samples followed by identical beta doses shows substantial usual shape of OSL decay. It gives significant growth in medium component and partial growth in fast component of OSL decay curve by diminishing the contribution of slow component (Figure 10).

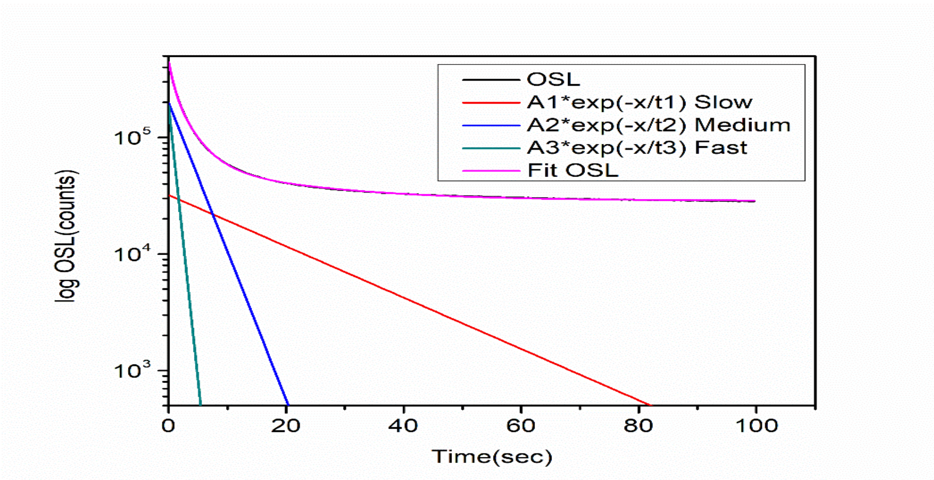


Figure 10: Multi components of OSL for 100seconds of stimulation in 1000oC annealed sample of 75.6Gy.

The changes in shape of OSL decay curve and OSL sensitivity followed by contribution of components suggest significant influence of strength of physical treatment to the sample and experimental condition. It may associate with the thermally and optically sensitive TL traps in identical sample. However, the TL glow curves have recorded after optical stimulation under identical physical conditions.

TL study after optical stimulation at 160oC for unannealed and annealed sample:

The influence of optical stimulation at 160oC on the TL glow curve pattern of unannealed and annealed sample have studied. It gives the information about the optical sensitivity of TL traps which may responsible for shapes of OSL decay curve followed by establish the correlation between OSL and TL. Either unannealed or annealed sample eliminates the contribution of 110oC TL glow peak during optical stimulation at 160oC. However, the contribution 220oC TL glow peak still observed and deep TL glow peak is developed at 390oC by complete bleaching of 332oC TL glow peak in unannealed sample followed by 5.04Gy dose. Under identical irradiation, the 600oC annealed sample exhibits the contribution of two distinct TL glow peaks at 260oC and 380oC by complete bleaching of 350oC TL glow peak. The position of 380oC and 220oC TL glow peak is sustained in 1000oC annealed sample by complete bleaching of 300oC and 370oC glow peaks. It reports that the rapidly bleachable TL glow peak which varies from 300oC to 350oC and their contribution may responsible for usual decay (Table 1). Also, the participation in optical bleaching with the stability of 220oC TL glow peak position suggests the optical sensitive nature TL trap and hence it may responsible to OSL decay which is associated with medium components of OSL decay. The deeper traps around 370-390oC TL glow peaks may attribute to either slower OSL decay or re-trapping of electrons during optical stimulation.

Table: Tra1 TL glow curves for unannealed and annealed samples before and after optical stimulation at 160oC for 100 seconds.

| AQ;oC 1 Hr | Dose (Gy) | OSL for 100sec | TL glow peaks at oC | | | | TL Intensity (counts) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tm1 | Tm2 | Tm3 | Tm4 | I1 | I2 | I3 | I4 |
| - | 5.04 | - | 108 | 220 | 332 | - | 1297.4 | 61.6 | 101 | - |
| - | 5.04 | 160oC | 219 | 391 | - | - | 15 | 20 | - | - |
| 600 | 5.04 | - | 113 | 351 | - | - | 38667 | 1252.6 | - | - |
| 600 | 5.04 | 160oC | 260 | 382 | - | - | 65 | 95.6 | - | - |
| 1000 | 5.04 | - | 122 | 218 | 300 | 370 | 202620 | 4468.8 | 618.8 | 772.8 |
| 1000 | 5.04 | 160oC | 221 | 382 | - | - | 171.4 | 32.2 | - | - |

The reasonable contribution of fast components of OSL might be due to close to typical rapidly bleachable TL traps which are seen in un-annealed and annealed sample prior to stimulation. The present investigations may suggest that contribution of medium and slow component is predominant compare to fast components of OSL. It indicates that OSL is not responsible to usual rapidly bleachable traps. The unusual shapes of OSL decay still appears even though OSL recorded at 160oC. It may suggest re-trapping of the optically released electrons still exist during optical stimulation but is not possible by usual shallow TL traps.

## III. CONCLUSION

The shapes of OSL decay curves are influenced by the strength of ionizing radiation, annealing treatment and optical stimulation temperature. Among of them, the impact of annealing treatment on shape of OSL decay followed by better OSL outcome is prominent. The shapes of usual OSL decay are attributed to the rapidly bleachable TL glow peak which varies from 300oC to 350oC and differ from typical rapidly bleachable TL glow peak. Also, the optical sensitive nature of 220oC TL glow peak and its stability is responsible to OSL process which is associated with medium components of OSL decay. The deeper traps around 370-390oC TL glow peaks are attributed to either slower OSL decay or re-trapping of electrons during optical stimulation at elevated temperature. The unusual shapes of OSL decay curved followed by poor OSL signal under influence of lower physical treatments are due to just a growth of two components and their re-trapping rather than participation in usual OSL decay.

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