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On Resolution of Optically Stimulated Luminescence Decay Curves Recorded at Room Temperature of Synthetic Quartz

Y.D. Kale[1]* and Y.H. Gandhi[2]

[1]*A D Patel Institute of Technology, New Vallabh Vidyanagar, Anand-388121, Gujarat, India*
[2]*Luminescence Research Laboratory, Applied Physics Department, Faculty of Technology & Engineering, The M. S. University of Baroda, Vadodara-390001, Gujarat, India.*

Abstract— *The Optically Stimulated Luminescence decay curves are recorded at room temperature for pre heat treated synthetic quartz followed by beta irradiations. The weaker OSL signals are obtained in the samples either for lower annealed sample or dose. The shapes of thus obtained decay curves are not usual exponential shape. The changes in OSL signal are attributed to the growth of different luminescence centers present in the sample during given physical treatment prior to measurement. The contribution of such center in OSL decay curve pattern has been resolved by operating exponential decay curve fitting method using microcal ORIGIN8.The findings of curve fitting data were corroborated with the ESR spectra.*

Keywords— *synthetic quartz crystal, thermal treatment, beta dose, OSL, TL*

1. INTRODUCTION

Either natural or synthetic quartz sample has large thermoluminescence (TL) glow peaks family and hence it is widely used for the dating and dosimetry application since many decades. These TL peaks have categorized into shallow, intermediate, easy/hard to bleach, deep peaks etc by implementing different protocols to the sample. **[1]** The present trends of research report that, the OSL has many advantages over TL. They also show significant correlation with TL peak wherein specifically reveal that the OSL efficiency widely depends upon the behavior of TL peak under different physical treatments. The recording of OSL at various temperatures is highly necessary for various reasons however; researchers working on dating side did not pay much attention on OSL of the quartz near room temperature. As dating workers consider exponential shape of decay curve as a symbol of best OSL efficiency therefore, they eliminate the role of 110°C shallow TL peak by suggesting OSL protocols at elevated temperature **[2]**. The present paper is aimed to throw the light on behavior of the OSL decay curve recorded at room temperature for the synthetic quartz specimens. The shapes of OSL decay curve, initial stimulation peak time (initial peak of decay curve as a function of time-ISPT) and OSL intensity of decay curves are considered for the present work. The changes in OSL output have been resolved by operating exponential decay curve fitting method using microcal ORIGIN8 software. These curve fitting data were corroborated with the ESR spectra to show the definite correlation of resolved components of OSL curve with TL results.

* *Corresponding Author Email: ydkale1@rediffmail.com*

2. EXPERIMENTAL DETAILS

The synthetic quartz crystal was collected from Center for Glass and Ceramic Research Institute Kolkata. The production detail of the crystal is explained elsewhere **[3]**. The samples were grinded through mortar and pestle to prepare standard grain particles. The grain size of 63-53μm was measured by ASTM sieves and used for the present work.

The grinded samples were collected in ceramic crucibles and prepared three different batches for annealing process. The annealing treatment was carried out through standard muffle furnace which has working capacity up to 1200°C with ± 1°C accuracy. First batch of the sample was held at 400°C for 1hr annealing duration and hence after the completion of required duration, the sample suddenly brought to room temperature as a quenching process. The process of annealing and quenching was repeated for second and third batches of the sample by holding at 600°C and 1000°C annealing temperature for identical annealing duration respectively. The thermally treated samples of 5mg from each batch were collected and spread out in the uniform layer over steel discs. The OSL decay curves and TL glow curves are recorded by RISO (TL/OSL-DA-15) reader which has inbuilt facility of beta (Sr90) irradiation source with dose rate of 0.084Gy/sec. The optical stimulation was carried out at room temperature (25°C) by 470nm wavelength of light for treated samples.

3. RESULTS AND DISCUSSION

3.1 Thermoluminescence Glow Curves are Recorded from 25°C to 573°C

Prior to measurement of OSL decay curve, it is essential

to record the TL glow curves between 25°C to 573°C to understand the position of TL traps in the material. These TL peak positions may help to resolve either correlation between components of OSL and TL. The annealed samples of 600°C and 1000°C were exposed to 5.04Gy beta dose exhibited well defined glow peak at 110°C. The additional TL peak at ~210°C along with 110°C is observed for higher annealed sample of 1000°C at identical beta dose. The noticeable growth in TL intensity and area under the TL curve has also been observed for 1000°C annealed material compared to 600°C. (Table 1).

Table 1: TL results of 63-53 µm annealed quartz followed by 5.04 Gy; AQ Hr:1

AQ (°C)	*TL peaks (°C)*		*TL(counts)*		*AUTLG*
	Tm_1	*Tm_2*	*I_1*	*I_2*	
600	113	351	38667	1513	1.83×10^6
1000	122	218	202620	3842	6.60×10^6

3.2 Optically Stimulated Luminescence Decay Curves Recorded at 25°C

In order to present investigations, the OSL decay curves are recorded at room temperature. Shapes of OSL decay curve, initial stimulation peak time and OSL intensity for different physical treatments of such recorded decay curves were obtained.

The annealed sample of 400°C for 1hour duration is exposed to different beta doses such as 2.52Gy, 5.04Gy, 25.2Gy and 75.6Gy. It is observed that the shapes of OSL decay curves do not have typical exponential decay for all the doses under study. OSL intensity increases initially then decreases with time of decay which gives a small peak at initial portion of the OSL decay curves, this ISPT decreases from 11.2sec to 0.4sec with the beta exposures. The area under decay curves and OSL intensity also decrease from 23728 counts to 19384 counts with the dose. But a significant change either in shape of decay curves or OSL intensity for 75.6Gy dose is noticed. The study clearly reveals that the pattern of decay curves start to shift from non-exponential shape to exponential side with beta doses (Fig.1).

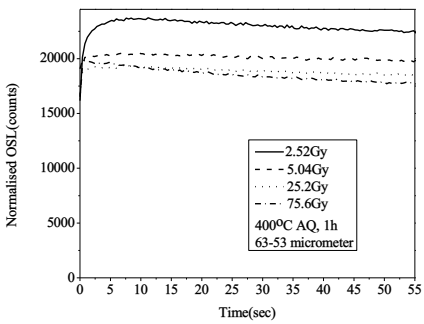

Fig. 1: Normalized OSL decay curves for 400°C annealed sample followed by different doses

The identical pattern of shape of OSL decay curves still exist in higher annealed sample of 600°C up to 25.2Gy beta dose and it disappears in higher annealed sample of 1000°C. The ISPT found to be reduced and the significant growth of OSL intensity is observed under these conditions. (Fig.2 & Fig.3).

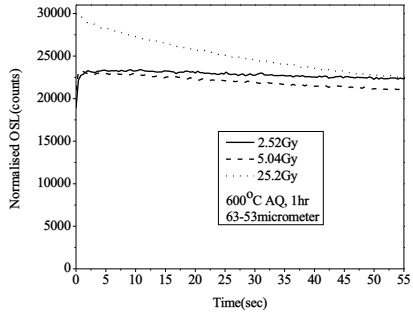

Fig. 2: Normalized OSL decay curves for 600°C annealed sample followed by different doses

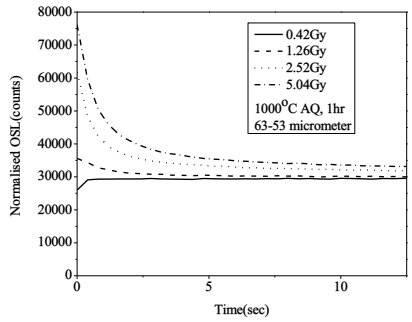

Fig. 3: Normalized OSL decay curves for 1000°Cannealed sample followed by different doses

The non-exponential shape of decay curves and its changes toward exponential shape of decay as a function of ISPT under influence of annealing treatment followed by different beta doses have been resolved by fitting suitable *expdecay3* equation $y = A_1 exp^{\frac{-x}{t_1}} + A_2 exp^{\frac{-x}{t_2}} + A_3\, exp^{\frac{-x}{t_3}} + y_0$ through ORIGIN8 software. It is noticed that the decay curve of 400°C annealed sample doesn't show best fitting for different beta exposures. While the fitting is better improved (adj R-square rises from 0.65 to 0.99) for 600°C annealed sample and it resolved only the single component of the OSL decay curve. The lifetime of this component of the OSL decay curve increases with rise in beta doses. In presence of single component, two more OSL components of the decay curves are observed by best fitted curves for 1000°C annealed sample followed by various doses. The lifetime of these multiple components of OSL decay curves decreases with doses (Table 2).

Smith et al.,[4] have shown that increase in OSL intensity means either ISPT is absolute zero or approaches to zero which leads to typical nature of exponential shape of decay curve. Such exponential decay curve is attributed to

systemic transition pathway of charges between various trapping sites and recombination centers. The disturbance in these pathways of charges may take place due to presence other electrons traps which are responsible for non-exponential part of the OSL decay curve. However, R M Bailey et al., have explained that the nature of non-exponential shape of OSL decay in quartz is attributed to the three various components of OSL decay curves corresponding to emptying of different type of the traps [5].

Table 2: OSL component data for different annealed samples followed by doses.

Gy	*600°C annealed*		
	Lifetime-1	*Lifetime-2*	*Lifetime-3*
2.52	8.64×10^{-4}	8.64×10^{-4}	8.46×10^{-4}
5.04	0.01176	0.01176	0.01176
25.2	0.02272	0.02272	0.02272
Gy	*1000°C annealed*		
	Lifetime-1	*Lifetime-2*	*Lifetime-3*
2.52	0.3968	2.0408	0.0270
5.04	0.3636	1.7241	0.0212

However, in present work, for 400°C and 600°C annealed samples, the OSL intensity doesn't increase till the ISPT reduced and approached to 0.4sec from its higher value of 11sec of ISPT with rise in beta irradiations. It may be due to the involvement of contribution of either slow or medium components of the OSL during optical stimulation. It has been resolved by the fitting data which reports the lifetime of this component of the OSL decay curve increases with rise in beta doses.

Further, the 0.4sec initial stimulation peak time still exist even though noticeable growth in OSL intensity is observed in both annealed samples. It may responsible for beginning of growth of new (Ge center in quartz) (Fig.4 & 5).

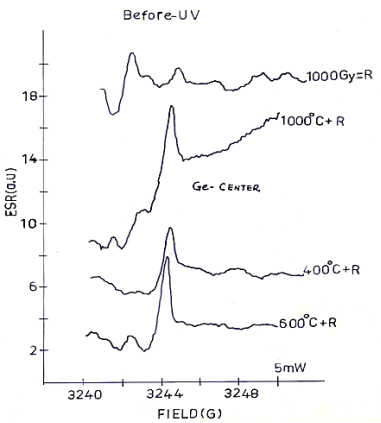

Fig. 4: Room temperature ESR spectra for Ge(g = 2.0000) center using 5mW microwave power.

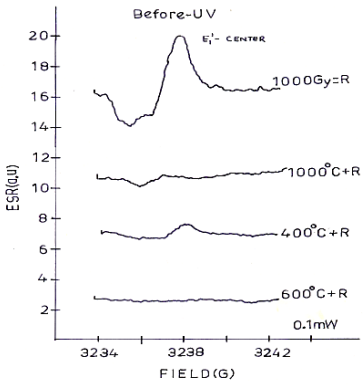

Fig. 5: Room temperature ESR spectra for E_1'(g = 2.0017) center using 0.1mW microwave power.

It shows the remarkable effect on shape of decay curve, initial stimulation peak time and OSL intensity by exhibiting traditional exponential shape of decay curve in 1000°C annealed sample. These results may correlate to the TL glow curves were recorded for identical sample prior to optical stimulation. The predominant effect of this center may recognize to the growth of one more component along with slow and medium components of the OSL decay curve which leads to decrease the lifetime of these multiple components of OSL decay curves with doses.

4. CONCLUSIONS

The changes in shape of OSL decay curve, initial stimulation peak time and OSL intensity are responsible to the role component of decay curves. The involvement of these components is function of the different physical treatment to the sample which leads to variations in lifetime of the charges. The variations in lifetime are attributed to the growth of new Ge centers along with slow and medium components of OSL decay curve.

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