The Effect Of Grain Size And β-Radiation Dose On Optically Stimulated Luminescence Of As-Received Synthetic Quartz

Sanskriti Parashar, Yogesh D. Kale, Yashesh H. Gandhi, Dattu R. Joshi

Abstract-In the present investigation, the effect of grain sizes of as received synthetic quartz samples and β-radiation dose on optically stimulated luminescence (OSL) were studied. The batches of different grain sizes (74-63µm, 63-53µm, 53-44µm, 44-37µm, and 37-25µm) were exposed by different β-radiation prior to OSL measurements at room temperature. For each grain size, an exponential shape of OSL decay curve was observed and maximum optically sensitive trap was turned to empty within 0 to 0.4 sec. Results indicated that the OSL intensity was increased with decrease in grain size from 74µm to 53µm whereas for the grain sizes below 53µm, the OSL intensities were started to decrease for each exposed sample. The variation in OSL intensity with grains sizes were due to the combined effect of the change in surface area and strength of radiation dose. The results were further elaborated by Fourier Transform Infra-Red (FTIR) analysis of prepared samples. The dose response curves were plotted and studied over the β-radiations from 2.63Gy to 131.33Gy for each grain size. Each grain size showed the supralinear behaviour of OSL signal over the dose range of 55.16 Gy to 131.33 Gy.

Index Terms- Synthetic quartz, grain size, β-radiation, OSL, FTIR, PACS No. – 78.60.Lc

1 INTRODUCTION

Since last decade, optically stimulated luminescence (OSL) technique had become a popular tool for the dating of archaeological and geological materials (natural quartz, Feldspar, Al_2O_3:C etc.) in comparison to of Thermoluminescence (TL) technique [1]. The OSL technique was first implemented by Huntley et al. (1985) for the optical dating of sediments [2]. Studies showed that materials can be used in powder form for OSL study in dosimetry and dating purpose. Literature also revealed that the new active/inactive TL and OSL sites were observed due to increased surface area after reduction in grain size of sample by grinding with mortar and pestle [3]. Researchers explained the effect of grain size on TL response of non-sensitized and sensitized natural quartz by the increase in specific surface area with decrease in grain size [4]. It was reported that the response of TL and OSL curve with respect to Dose was an essential factor in any dating procedure. These findings could be used to estimate the equivalent dose in dating [5]. It was also observed that the OSL intensity of synthetic quartz was influenced by various physical conditions such as radiation dose, annealing temperature, annealing period and elevated temperature [6], [7], [8].

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But there is no literature available for the comparative study on the effect of different radiation dose on different grain size for OSL intensity of synthetic quartz. The aim of present study was to understand the effect of grain size and different β-radiation dose on OSL intensity of as received synthetic quartz at room temperature for dating application. Five different grain size (74-63µm, 63-53µm, 53-44µm, 44-37µm, and 37-25µm) of synthetic quartz were prepared by using mortar pestle. OSL intensities were measured for every grain size irradiated with different β-radiation. The dose response curves were plotted and analysed over the radiation dose range from 2.63 Gy to 131.33 Gy for each grain size. The obtained results have been supported by corresponding changes in Fourier Transform Infra-red spectra of prepared synthetic quartz samples.

2 EXPERIMENTAL DETAILS

2.1 Method of sample preparation

The synthetic quartz sample was kindly provided by CGCRI, Kolkata. Five different sizes of as received synthetic quartz sample were prepared by grinding the sample using mortar-pestle. The crushed sample was passed through different sieves having different mesh size, to achieve the samples of desired grain sizes [i.e. 74-63µm, 63-53µm, 53-44µm, 44-37µm, and 37-25µm].

2.2 Characterization

Each grain size sample was exposed to different β-radiation dose (2.63 Gy, 15.76Gy, 28.89Gy, 55.16Gy, 81.43 Gy, 107.69 Gy, and 131.33 Gy) at the dose rate of 7.88Gy/min at room temperature. Then OSL decay curve were recorded for 0 to 100 sec at room temperature by using Risø TL/OSL reader (model TL/OSL-DA-20) having 470 nm laser line or broad band stimulation wavelength. OSL intensity was normalized by weight for each grain size sample. Fourier transfer infrared (FTIR) spectroscopy [MIRacle10 Single Reflection ATR Spectroscopy (IRAffinity-1) Shimadju] was used for the examination of impurities and defect in the prepared sample.

3 RESULTS AND DISCUSSION

OSL decay curves of different grain sized synthetic quartz samples, followed by different β-radiation doses were recorded at room temperature from 0 to 100sec dose (Fig. 1(a), Fig. 1(b), Fig. 1(c), Fig. 1(d) and Fig. 1(e)) For each grain size, an exponential (I max at t=0) shape of OSL decay curve was observed. The initial OSL intensity was gradually increased with increase in dose. It was also found that maximum optically sensitive trap was turned to empty within 0 to 0.4 sec after that slow decay was obtained for 0.4 to 50 sec. As radiation dose increased, faster decay of optically sensitive trap was observed than decay at lower beta dose. The comparative study of decay curves for different grain sized samples followed by different radiation dose explained that the OSL intensity was increased with decrease in grain size up to 53 µm whereas, it started to decrease below 53 µm to 25 µm (Fig. 2). The modification in surface area due to different grain size and strength of β-radiation dose were prime responsible factors for changes in OSL signal intensities of prepared samples.

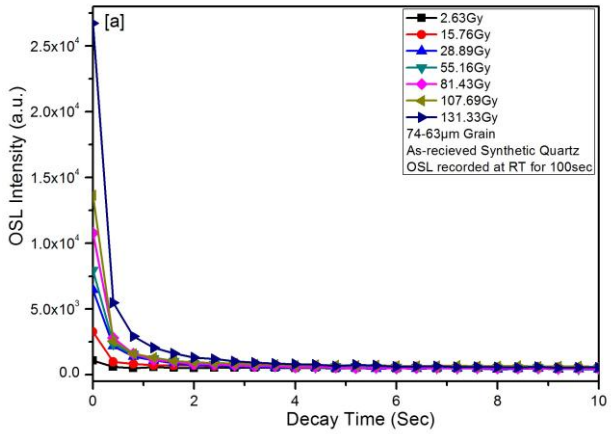

Fig. 1(a). *OSL decay curve recorded at Room Temperature for 74-63 µm grain size samples of synthetic quartz.*

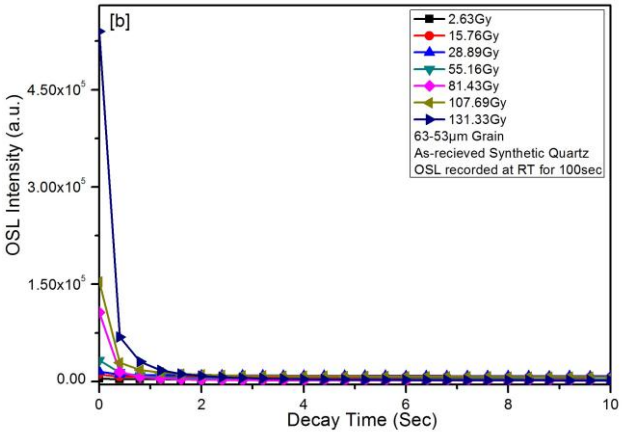

Fig. 1(b). *OSL decay curve recorded at Room Temperature for 63-53 µm grain size samples of synthetic quartz.*

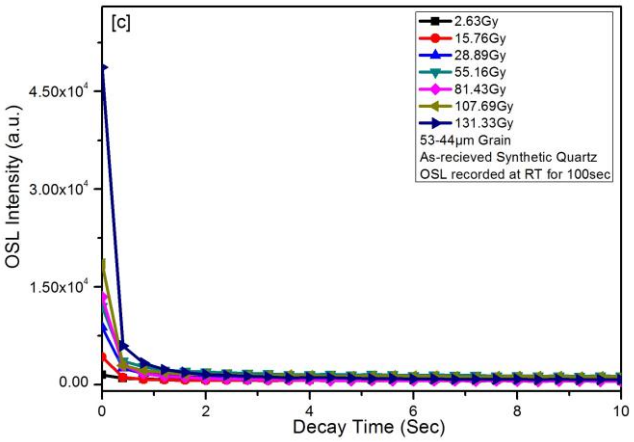

Fig. 1(c). *OSL decay curve recorded at Room Temperature for 53-44 µm grain size samples of synthetic quartz.*

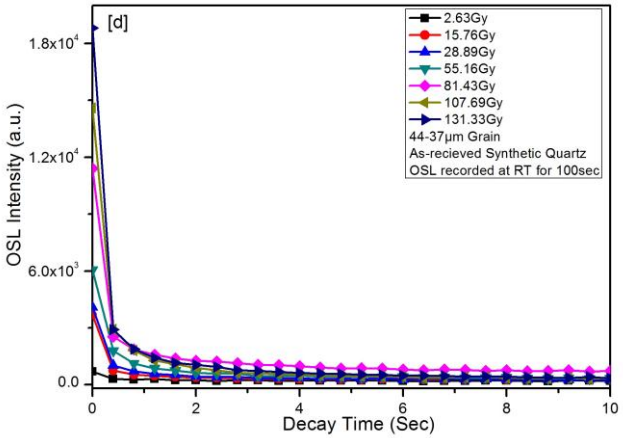

Fig. 1(d). *OSL decay curve recorded at Room Temperature for 44-37 µm grain size samples of synthetic quartz.*

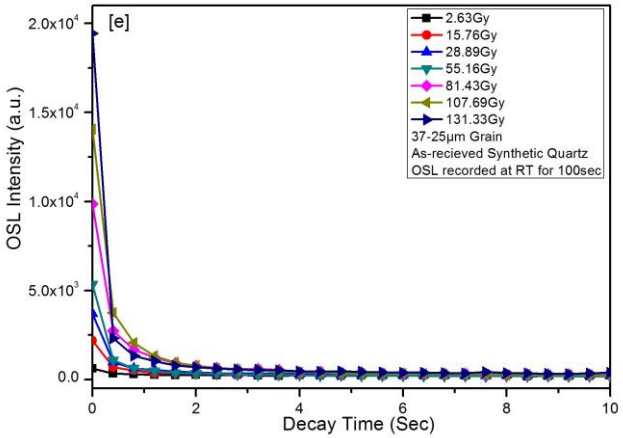

Fig. 1(e). *OSL decay curve recorded at Room Temperature for 37-25 µm grain size samples of synthetic quartz.*

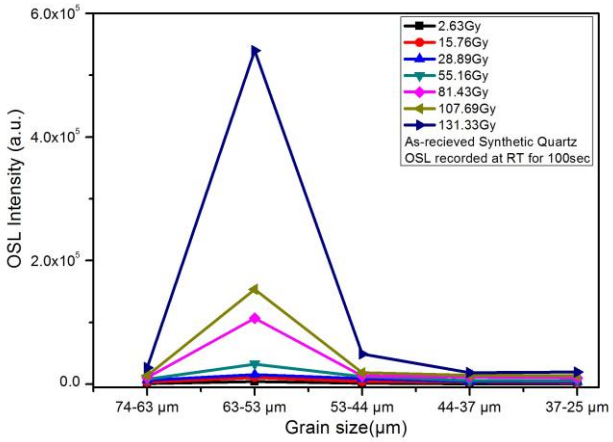

Fig. 2 *Comparative study of OSL intensity for different grain sizes at different beta radiation dose.*

Expression (1) was widely used by many scientists to find OSL/TL intensity:

$$I_{max} = a.D^{k} \quad (1)$$

Where, D is absorbed dose; a and k are constant.

By plotting (1) on log-log scale, a graph was obtained with slope k. The value of k>1, indicated the supralinearity of decay curve, while k<1 and k=1 represent the sublinear and linear nature of curve respectively. Degree of supralinearity can be directly calculated by the value of k [9]. The OSL dose response curves were plotted on log-log scale over the radiation dose range from 2.63 Gy to 131.33 Gy, to observe the behaviour of obtained curves (Fig. 3). The k-values for the plotted OSL dose response curves are summarized in Table 1. The results explained the supralinear behaviour of curves in the dose range of 55.16Gy-131.33Gy (k>1) and sublinearity in the dose range of 2.63Gy-55.16Gy (k<1) for all grain sizes. It was also observed that the degree of supralinear was increased for grain size 74 µm to 53µm and decreased up to 25µm.

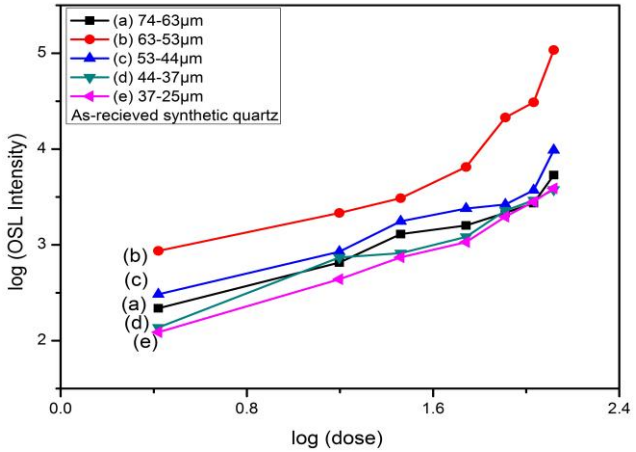

Fig. 3. *OSL dose response curve for (a) 74-63 µm, (b) 63-53 µm, (c) 53-44 µm, (d) 44-37 µm and (e) 37-25 µm grain size samples of synthetic quartz.*

In Fig. 4, the IR spectrums for different grain sizes of synthetic quartz samples showed a series of absorption peaks from 600 cm-1 to 4000 cm-1. To be precise, a broadband between 3200 cm-1 to 3600 cm-1 is corresponded to the O-H stretching mode of hydroxyl group, whereas the peak observed between 900 cm-1 to 1100 cm-1 is assigned to silicate ion [10]. It was observed that as the size decreased, the hydroxyl group content increased in the prepared samples. Here it is an important fact that the hydroxyl group acts as a non-radiative recombination center [11].

Table 1. k values for 74-63 µm, 63-53 µm, 53-44 µm, 44-37 µm and 37-25 µm grain size samples of synthetic quartz at different β-radiation dose range.

Grain Size (µm)	k value	
	For dose 2.63-55.16Gy	For dose 55.16-131.33Gy
74-63	0.71	1.27
63-53	0.52	2.98
53-44	0.69	1.44
44-37	0.78	1.28
37-25	0.74	1.46

Note: µm= micrometre, Gy= Gray.

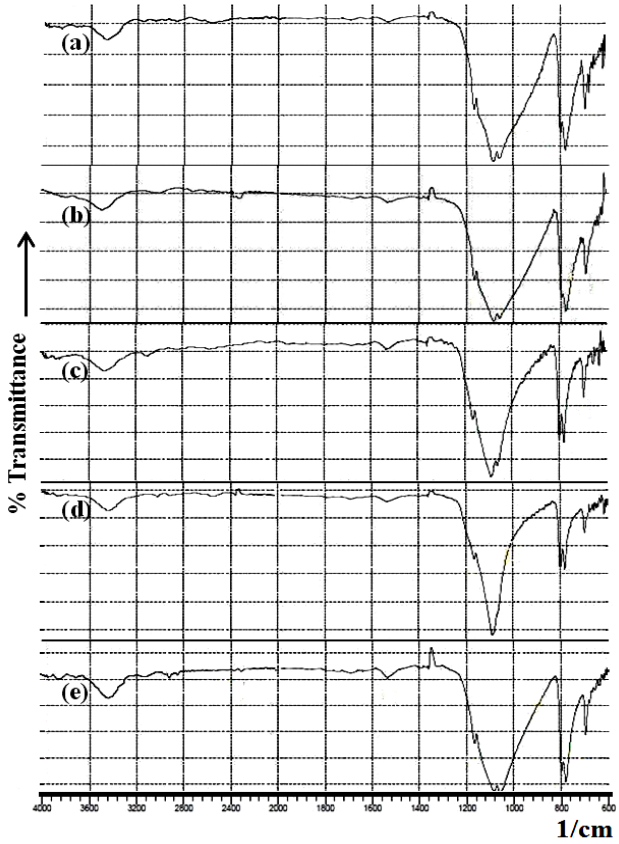

Fig. 4. *FTIR spectrums for (a) 74-63 µm, (b) 63-53 µm, (c) 53-44 µm, (d) 44-37 µm and (e) 37-25 µm grain size samples of synthetic quartz.*

Surface area of samples increased upon size reduction which might lead to creation of new active/inactive OSL surface sites inside the sample [3]. So, newly developed active OSL sites may be responsible for the increased OSL intensity for grain size 74µm to 53 µm. Luminescence intensity is affected by the defect concentration of both impurity and intrinsic defect [12]. For example, surface impurities such as hydroxyl are known to quench the excitons luminescence [11]. From FTIR results, hydroxyl group acted as non-recombination center which was responsible for decrease in OSL intensity with decrease in grain size from 53µm to 25µm. Nonradiative radiation due to non-recombination center may dominate on radiative radiation through new active OSL sites which might be responsible for decrease in OSL intensities below 53µm.

Supralinear and sublinear behaviour of OSL dose response curves had been explained by various researchers with the help of different models. Literature clearly explained the importance of competition effect between traps & centers and specific behaviour of material during excitation and read out for different OSL dose responses [13]. Researchers explained the sublinear behaviour with one trap-one recombination center (OTOR) model when traps are far from saturation [14]. In present work, all grain size showed sublinear dose dependence in low dose (from 2.63 Gy to 55.16Gy) and turned to supralinear at high dose range (55.16Gy to 131.33Gy). The reason for this sublinearity may be due to the competition between the trap and the recombination center for free electrons during irradiation. The conversion of sublinearity into supralinearity indicated that the competitors/electron traps were increased due to increased irradiation [15] and faster decay curve was observed at high radiation dose in comparison to decay at lower dose.

4 CONCLUSION

OSL intensity was increased in synthetic quartz samples having grain size from 74µm to 53µm and then decreased with lower sizes up to 25µm due to formation of new centers. In addition to that, OSL intensity was also increased with increased dose of β-radiation. Sublinearity was observed at low dose range of radiation (2.63Gy to 55.16Gy) which turned to supralinear at higher dose (from 55.16Gy to 131.33Gy). FTIR spectrums of prepared samples supported the results of respective OSL decay curves and OSL dose response curves. So from the presented data in the article, it can be concluded that grain size of synthetic quartz material and radiation dose has combined effect as well as high impact on OSL intensity of prepared samples. These outcomes of the research can be further used in dating applications.

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