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Study Some of Optical and Thermoluminescence Properties of Muscovite Mica Exposed to Ultraviolet Radiation

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Abstract
Thermoluminescence properties of ultraviolet-irradiated muscovite sample from Egypt have been studied. One TL peak is observed in the natural material around 190℃. A linear response curve to ultraviolet radiation was obtained over the exposure time ranging from 15min to 75 min. A fading study over a period of 15 days shows that the UV-exposed aliquots faded by 27% when exposed for 150 min. The optical direct band gap decreased closely from 3.2eV to 3.1eV after irradiation which means improving crystallinity. Urbach energy decreased from 1.9eV to 1.8eV after irradiation shows less structural disorder. These results further indicate the potential of muscovite as a phosphor in retrospective dosimetry and TL dating.

Keywords: Muscovite, optical properties, thermoluminescence properties,ultraviolet-irradiation.

1. Introduction

Muscovite is the most common form of mica. Its name is derived from "Muscovy Glass", which describes thick sheets of transparent mica. Its presence is noted especially in granite pegmatites, in contact metamorphic rocks, in metamorphic schists, and in hydrothermal veins. Important muscovite deposits where large significant crystals occur are almost exclusively from granite pegmatite [1]. Mica is invaluable in the Electrical industry because of its unique combination of physical, chemical and thermal properties. TL studies of mica might be interesting from a fundamental point of view as well.

First suggestions about a weak TL signal of biotites and muscovites were published by McDougall [2]. Some TL properties in muscovite were investigated [3]. Mukhlya et al. [4] studied the stage of mineralization through the TL characteristics of muscovite. Natural mica from a granite-pegmatite pre-Cambrian rock was studied [5]. Another study was focused on the TL sensitivity changes and the kinetics of the luminescence process in muscovite [6].

Thermoluminescence studies of two types of muscovites taken from two deposits in the Southwestern Nigeria have been carried out in order to examine their potential for TL dosimetry and dating. The TL glow curves are shown to be deposit specific but with some common properties [7]. Analysis of the thermoluminescence glow curves of muscovite and calculation of trapping parameters for individual de convoluted peaks for 25 kGy gamma irradiated of unsensitized and sensitized mica have been done using glow curve de convolution software[8].

Among minerals, muscovite mica is one of the most inexpensive and abundant mineral that has enormous dosimetric and dating potentials [9].

Clark and Sanderson [10] studied the highly sensitive blue and near-ultraviolet emission band of natural mica. The natural as well as beta, gamma and electron beam induced TL characteristics of different types of synthetic and natural mica from different origins have been extensively studied by many other researchers, [11- 15].

The thermal quenching activation energy and pre-exponential suggested that non-radiative recombination increases with higher heating rates in natural muscovite sample [16].

The glow curves of muscovite are analyzed by T_m–T_{stop} analysis, peak shape method and fractional glow technique. Analyses showed that there is a trap center and a radiative recombination center at depth around 0.71 and 2.78 eV from the conduction band. Due to UV irradiation on the excited sample, the transfer of trapped charges from the deeper trap level (1.23 eV) to the shallow level (0.71 eV) has been observed [17].

The present work summarizes the results of preliminary studies of the TL characteristics of muscovite after UV irradiations in order to investigate its capability for use as an UV detector material.

2. Experimental

The used muscovite sample is in thick flakes, micaceous mass groupings, tabular, foliated, flaky, and scaly extracted from a granite-pegmatite pre-Cambrian rock chemical formula: $KAl_3Si_3O_{10}(OH)_2$, color: yellow, hardness: 2 - 2.5, crystal system: monoclinic. The investigated material was provided by the Geological

Department, Faculty of Science, Ain Shams University and originated from Eastern Desert, in Egypt. The UV – Vis transmission spectroscopy (Perkin Elmer) was performed on the samples before and after irradiated by using an UV Mercury lamp with the wavelength 254nm.The analytical wavelength was in the range of 200-1100nm. The transmission spectra were transferred into absorption spectra. The direct and indirect band gap was obtained by analyzing these spectra.

UV irradiations for TL measurements were performed at zero temperature in air. TL measurements were monitored using a Harshaw 3500 TLD reader. Light pulses were detected by the photomultiplier tube provided with a narrow band blue filter plus Schoot BG39 glass filters of blue- violet transmittance band. A linear heating rate of 5 $^{\circ}$Cs^{-1} was chosen; heating the sample from room temperature up to 400 $^{\circ}$C. The incandescent background was measured then subtracted from the data. To minimize the statistical error, five aliquots of an average weight 2mg were used for each measurement. All irradiations and measurements were performed in King Saud University, Saudi Arabia.

3. Results and discussion

3.1 Optical properties

Mica muscovite sample was annealed for 15 minutes in oven with $250^{\circ}C$, and then the sample was irradiated by using UV lamp with 254nm wavelength for 150 minutes.

Fig.1 shows the absorption spectra of mica muscovite before and after irradiated by 254nm UV light in the wavelength range of 200nm-1100nm. The transmission spectra were transferred into absorption spectra.

The samples showed significant absorption in the visible light region. The absorption edge was shifted from about 530nm towards high wavelength 550nm after irradiation. The UV-Vis absorption spectra were used to investigate the structure transition and defect information in crystalline and non-crystalline materials [18].

The optical direct band gap of mica muscovite before and after irradiation using 254nmUV lamp can be calculated using Taucs equation (1) which relates the absorption coefficient α and incident photon energy hv by the following:

$$\alpha(hv) = \frac{B(hv - E_g)^n}{hv} \dots\dots\dots\dots 1$$

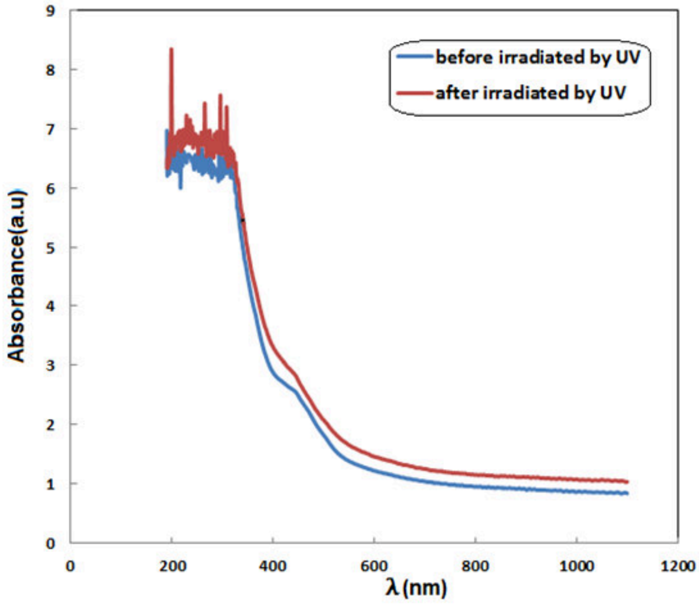

Fig.1: UV absorption spectra of muscovite mica before and after irradiated by (254nm UV lamp)

Where B is the correction coefficient, E_g is the band gap of the material.

When n=2, the equation1 stands for the direct band gap, the band gap energy were calculated by the equation:

$$E_g = \frac{hc}{\lambda} \dots\dots\dots\dots..2$$

Where h Plancks constant, c the speed of the light and λ is the related wavelength. According to the equation 1 and 2.

Fig.2 shows the direct optical transition involved a plot of $(\alpha hv)^2$versus (hv) according to the equation 1 and 2, where (v) the light frequency, yields a straight line with the energy intercept of the direct band gap, the optical direct band gap decreased from 3.2eV to 3.1eV after irradiation by UV -254 nm lamp correspond to an electron transition [19].

Decreasing of energy band gap could be due to crystallinity improvement of the sample [20].

Fig.3 shows plots of $\ln\alpha$ versus (hv) used for calculating the Urbach energy, the Urbach energy values decreased closely from 1.9eV to 1.8eV after irradiation which shows less structural disorder [20].

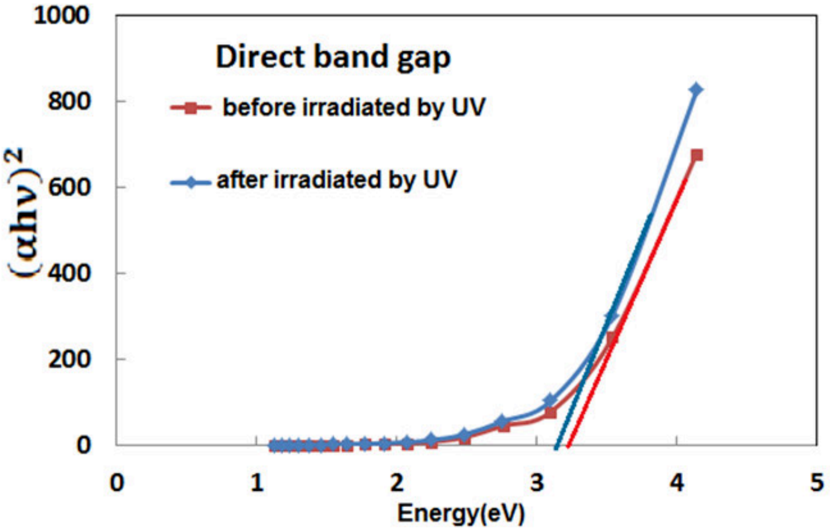

Fig.2: Plots of optical direct band gap of muscovite mica before and after irradiated by (254nm UV lamp)

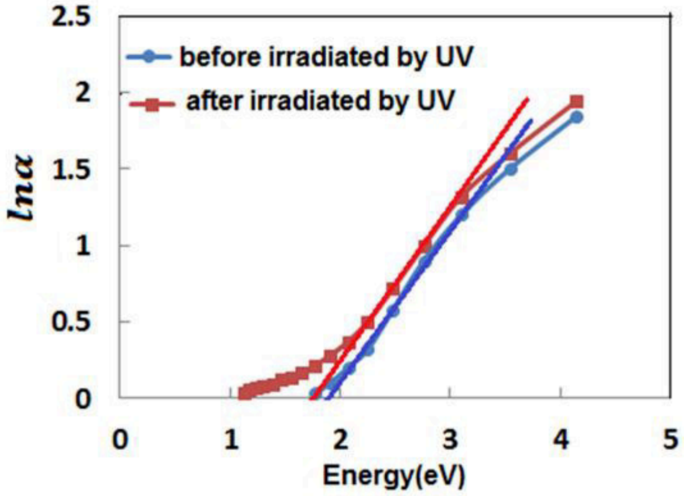

Fig.3: Plots of Urbach energy of muscovite mica before and after irradiated by (254nm UV lamp)

3.2 Natural sample glow curve

The glow curve of the natural sample (without any treatment in the laboratory) recording in the blue band, exhibited one peak centered around190°C (Fig.4a). This peak is attributed to irradiation from a number of sources which include self-irradiation, irradiation from surrounding geological formations prior to sampling and from cosmic sources. This peak may be a result of the existence of closely spaced trapping centers for which individual glow peaks could not be resolved. This indicates a complex trapping system in the investigated material. The previously investigated natural muscovite [3-7] exhibit natural TL peaks in the high temperature range of 220°C–350°C. In un-annealed muscovite sample from India, a TL peak has been observed at around 348 K [18].

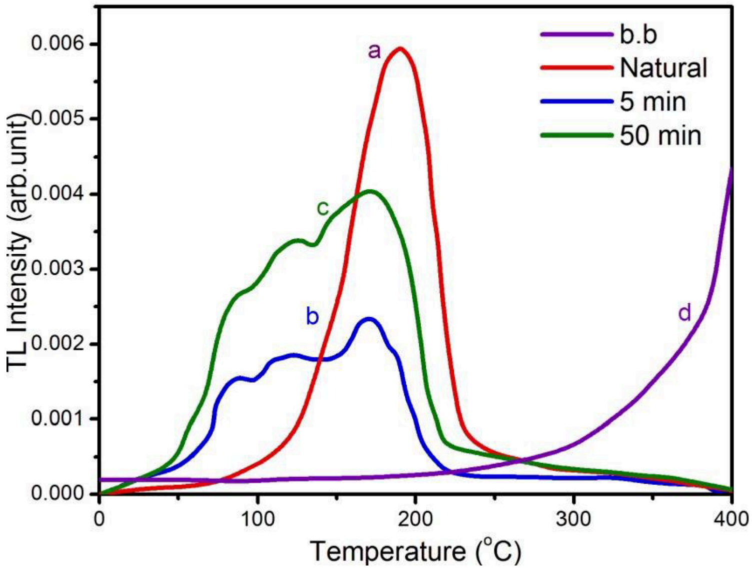

Fig. 4. Examples of glow curves: (a) unbleached, natural thermoluminescence; (b) after 5 min bleaching in muscovite; (c) after 50 min bleaching; and (d) the background black-body signal.

3.3. Bleaching effect

Muscovite was irradiated with U.V. photons for different periods of time, ranging between 5 and 50 min in air. The average response of 5 aliquots is plotted in Fig.5.The aliquots are uniformly irradiated with ultra violet radiation (254 nm) while held at room temperature. The major effect of UV exposure is a very strong transfer to the 190°C TL peak after optical exposure was observed. New peaks were induced at 85°C, 110 °C and 170°C. However, shows that, in fact, most of the decrease in TL occurs at about 190°C. These new peaks appear after the UV exposure because of optical transfer and the TL produced in this way is referred to as photo-transferred TL (PTTL). In Fig. 5, the TL signals were integrated over a temperature range of room temperature to 400°C . Bleaching continues more slowly until 50 min, showing an exponential decrease I= I_0+Ae^ (-X/t) against bleaching time with decay constants of I_0= 0.404, A= 0.60, t=105.727.

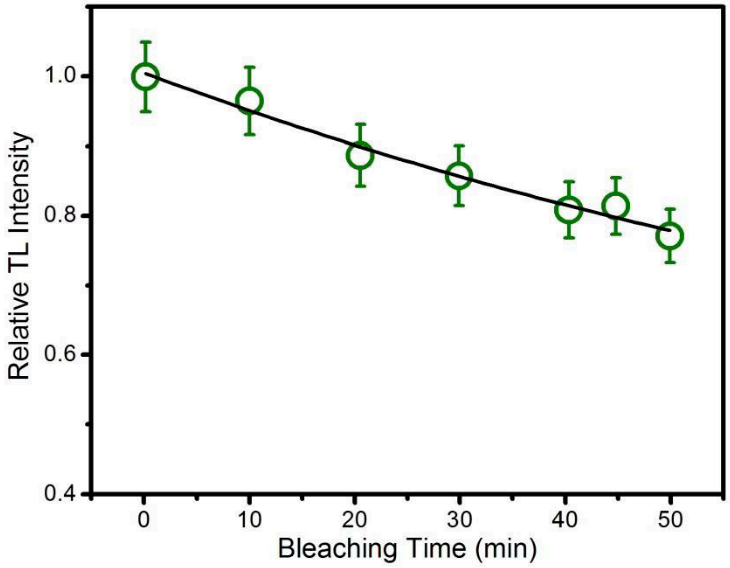

Fig.5 The dependence of the thermoluminescence, integrated from room temperature to 400°C, on bleaching time.

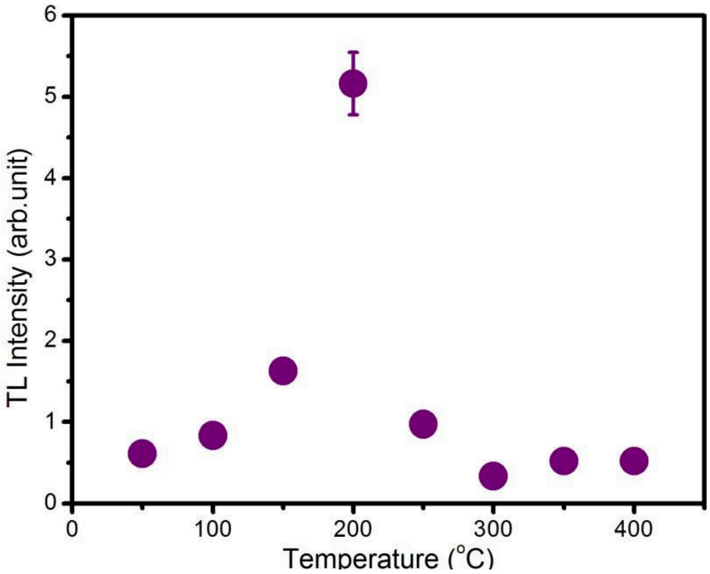

Fig 6: The variations of the TL response of mica with the pre-heating temperature.

3.4. Thermal Treatment

The investigated material was pre-heated at different temperatures ranging from50°C to 400°C for 15 min, cooled in air and subsequently irradiated to an UV time of 150 min at zero temperature to avoid bleaching. After irradiation the TL spectrum was read out. The main effect of this thermal treatment is an increase of the TL signal with increasing temperature. The sensitivity of mica annealed at 200°C for 15 min is found to be ten times that annealed at 400°C (Fig. 6).

It is known that thermal treatment produces some changes in the population of radiation induced defects or in the diffusion of impurities to the lattice, or interstitial sites at which they constitute effective trapping centers [22, 23].This explains the increase in TL intensity up to 200°C. The reduction of TL intensity at temperatures >200°C can be attributed to thermal quenching [23].

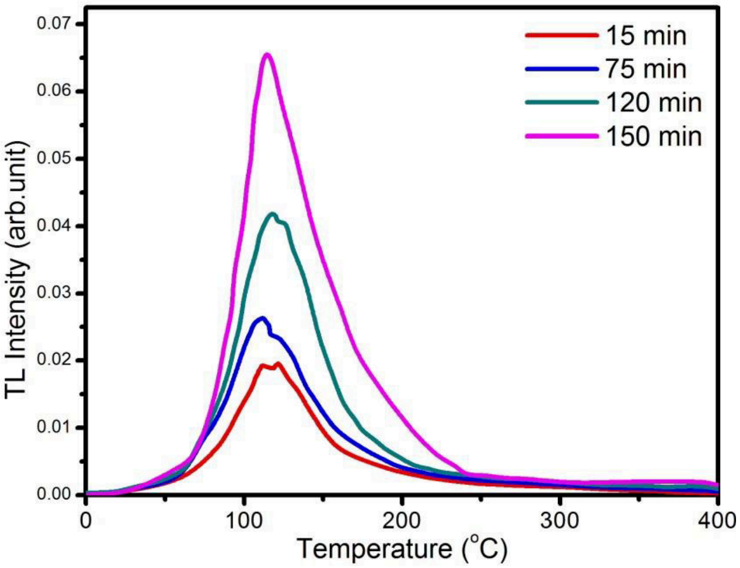

Fig.7. Thermoluminescence glow curves of muscovite after exposure to UV.

3.5 Laboratory induced glow curves

Because of the inhomogeneous distribution of impurities within the sample it was oven annealed, at 200°C for 15 min, before the irradiation in order to homogenize the impurities, as a result all the trapped electrons and holes constituting the natural TL were removed and the sample TL reading is very close to background.

As observed in Fig.7 mica appears as a very sensitive material for UV radiation at zero temperature. At low exposure starting at 5min, the glow curves show two peaks at 110°C and120°C .This means that the traps related to the low temperature peaks were first to be populated since their traps were all emptied. This means that the capture cross section of the carriers in the traps associated to these peaks are much higher than the corresponding value for the other peaks. It was found that these peaks are shifted to 115°C and 125 °C when the exposure time increases to 120 min. After 150 min of UV exposure, the glow curves show only one peak at 115°C, after which no response to laboratory UV irradiations was observed.

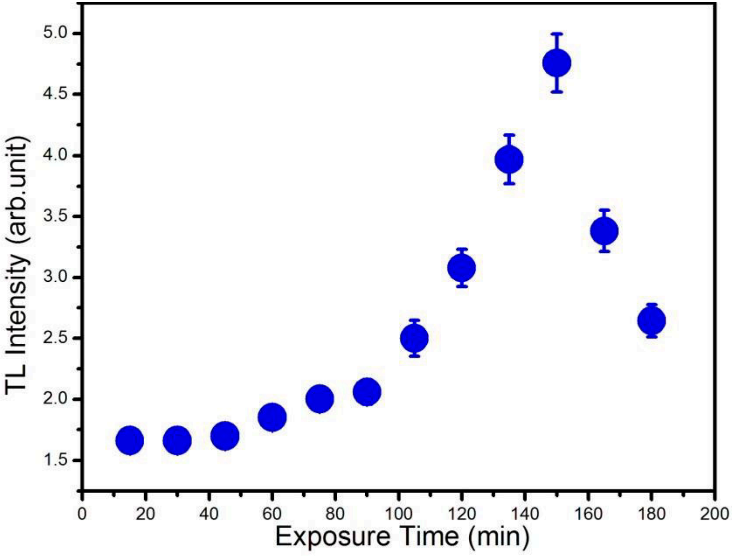

Fig. 8. TL–UV exposure response curve of muscovite.

3.6. TL- UV response

The dose response of UV irradiated muscovite was investigated by plotting the integrated TL signal as a function of exposure time of UV as shown in Fig. 8. It is clear from this figure that the TL response follows the relations ($I = 1.517+0.006t$) and ($I= 0.001t^{1.6676}$) over the ranges (15min-75min) and (90 min-150 min) of UV exposure time where I is the integrated TL intensity in arb. unit, t is the exposure time in min. Radiation damage occurs after 150 min of UV exposure. The linear region of dose response is believed to arise from recombination between locally trapped electron hole pairs in spatially correlated trapping centers and luminescent centers [24]. According to this response the natural sample TL intensity corresponds to a laboratory irradiated one with an UVR (λ=254nm) for 2.4 h at zero temperature.

3.7 Storage effects

The TL fading of laboratory induced TL signal (150 min of UV exposure) given to annealed aliquots is studied over a period of 15 d. The large amount of annealed muscovite was irradiated and stored for a period of 15 d in dark at room temperature before the TL reading, the small amount of it used as the control, being stored first, then irradiated with a dose identical to that above and read out immediately on the same day to avoid variations from instrumental drift.

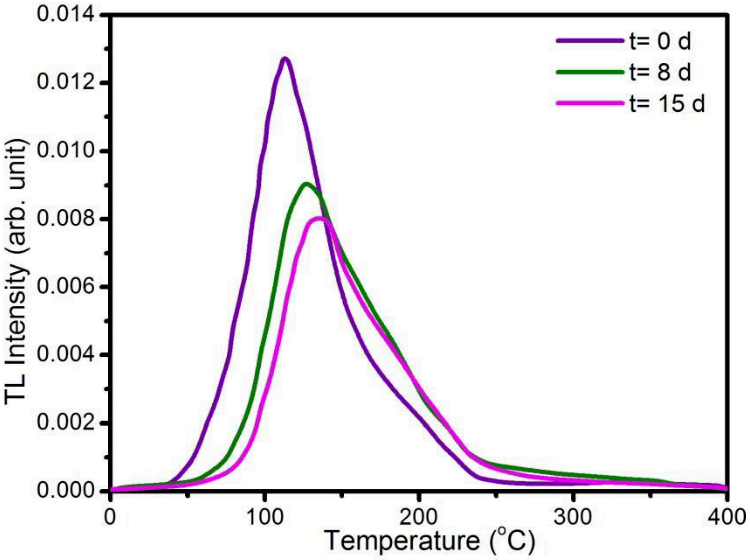

Fig.9: The effect of room temperature dark storage upon glow curves of muscovite.

The TL signal behavior is associated with the probability of electron release from the shallower traps (Fig.9) that occurs very fast at room temperature. 15 days later, the electron population decreases asymptotically by the X-axis and the involved electrons are located in deeper traps; consequently, more energy is needed to leave their positions at room temperature.

The TL signal was found to be (86%) after a delay period of 8d and to settle down a value of 73% of the initial value after 15 days of storage (Fig.10).

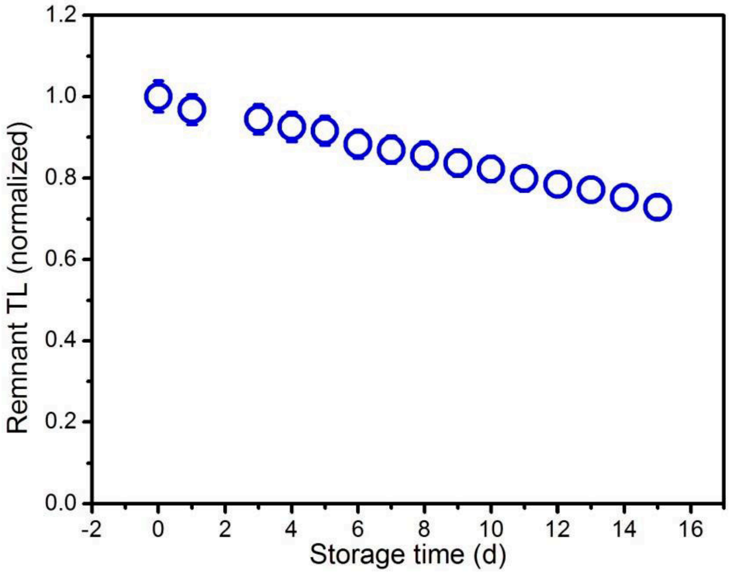

Fig.10: TL fading of muscovite.

5. Conclusion

Muscovite shows promise as a phosphor for the detection of UV (with corresponding converters) in the range 5min-75 min in the blue emission band. The low bleaching effect promises that this material could be used as a detector at room temperature. Radiation damage occurs after 150 min of UV exposure. According to this response the natural sample TL intensity corresponds to a laboratory irradiated one with an UVR (λ=254nm) for 2.4 h at zero temperature.

The optical direct band gap decreased closely from 3.2eV to 3.1eV after irradiation which means improving crystallinity. Urbach energy decreased from 1.9eV to 1.8eV after irradiation shows less structural disorder.

A crucial feature of the material is the fading of the TL signal (~27% loss after 15 d). This problem may be solved by using a suitable post-irradiation heat treatment procedure. Further, more accurate studies will show whether this material can be used for the measurement of solar spectral irradiation as a personal UV dosimeter.

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