Thermochimica Acta 585 (2014) 45–49

Contents lists available at ScienceDirect

Thermochimica Acta

journal homepage: www.elsevier.com/locate/tca

Reduction of thermal quenching of biotite mineral due to annealing

J.M. Kalita *, G. Wary

Department of Physics, Cotton College, Guwahati 781 001, India

ARTICLE INFO

Article history:
Received 11 February 2014
Received in revised form 28 March 2014
Accepted 28 March 2014
Available online 8 April 2014

Keywords:
Thermoluminescence
Thermal quenching
Activation energy
Annealing

ABSTRACT

Thermoluminescence (TL) of X-ray irradiated natural biotite annealed at 473, 573, 673 and 773 K were studied within 290–480 K at various linear heating rates (2, 4, 6, 8 and 10 K/s). A Computerized Glow Curve Deconvolution technique was used to study various TL parameters. Thermal quenching was found to be very high for un-annealed sample, however it decreased significantly with increase in annealing temperature. For un-annealed sample thermal quenching activation energy (W) and pre-exponential frequency factor (C) were found to be $W = (2.71 \pm 0.05)$ eV and $C = (2.38 \pm 0.05) \times 10^{12}$ s^{-1} respectively. However for 773 K annealed sample, these parameters were found to be $W = (0.63 \pm 0.03)$ eV, $C = (1.75 \pm 0.27) \times 10^{14}$ s^{-1}. Due to annealing, the initially present trap level at depth 1.04 eV was vanished and a new shallow trap state was generated at depth of 0.78 eV which contributes very low thermally quenched TL signal.

1. Introduction

The intrinsic (i.e. lattice defects) and/or extrinsic (i.e. impurities) defects as well as structural defects and their distribution in the lattice are responsible for the luminescence emission which are commonly observed in insulator materials during excitation with electrons, ions, UV, or other ionizing radiation. Luminescence techniques, such as thermoluminescence (TL), photoluminescence (PL), cathodoluminescence (CL), optically stimulated luminescence (OSL), etc. are usually employed not only for dosimetric purposes (dating, retrospective dosimetry, or radiological terrorism), but also for material characterization. All factors involved in the luminescence phenomena (i.e., lifetime, efficiency, emission spectra, etc.) depend directly on the crystalline phase, which is mainly influenced by pressure and temperature. Thus, small variations in the lattice structure due to the presence of inclusions, impurities, substituted ions, or surface defects in ppm concentration shows changes in the intensity and wavelength position in the emission spectra [1] as well. Another well-known phenomenon, thermal quenching [2–4] has been observed in many thermoluminescent materials at higher heating rates. The effect of thermal quenching plays an important role in TL study on which many applications of TL are based.

Biotite is a black silicate mineral within the mica group. The chemical formula of biotite is $K(Mg,Fe)_3AlSi_3O_{10}(F,OH)_2$. It consists of flexible sheets which can easily flake off. Iron, magnesium, aluminum, silicon, oxygen, and hydrogen form sheets that are weakly bound together by potassium ions. It is an important mineral used as a surface treatment in decorative concrete, plaster and other construction materials. It is found in many types of igneous rocks and in some metamorphic rocks. Biotite is also used to constrain ages of rocks by potassium–argon dating or argon–argon dating [5]. It is sometime used in assessing temperature histories of metamorphic rocks, because the partitioning of iron and magnesium between biotite and garnet is sensitive to temperature. TL studies of biotite mica might be interesting from a fundamental point of view as well. Because of its layered structure, the comparison to other types of silicate, such as muscovite, quartz and feldspars, may provide information about the motion of charge carriers in anisotropic crystals. The changes in the TL sensitivity of un-annealed X-ray induced biotite under various heating rates were studied by J.M. Kalita et al. [6].

In the present work TL of X-ray irradiated natural biotite annealed 473, 573, 673 and 773 K were studied within 290–480 K at various linear heating rates. A Computerized Glow Curve Deconvolution technique was used to study various TL parameters. The effect of annealing on thermal quenching of biotite mineral has been reported.

2. Experimental details

Black color-bladed biotite sample was procured from Patharkuery, Kamrup district of Assam (India). It is located at latitude 26°11′ N and longitude 91°44′ E. It was crushed by roll

* Corresponding author. Tel.: +91 9707740363.
E-mail addresses: jitukalita09@gmail.com, ganesh_wary@yahoo.co.in (J.M. Kalita).

http://dx.doi.org/10.1016/j.tca.2014.03.047
0040-6031/

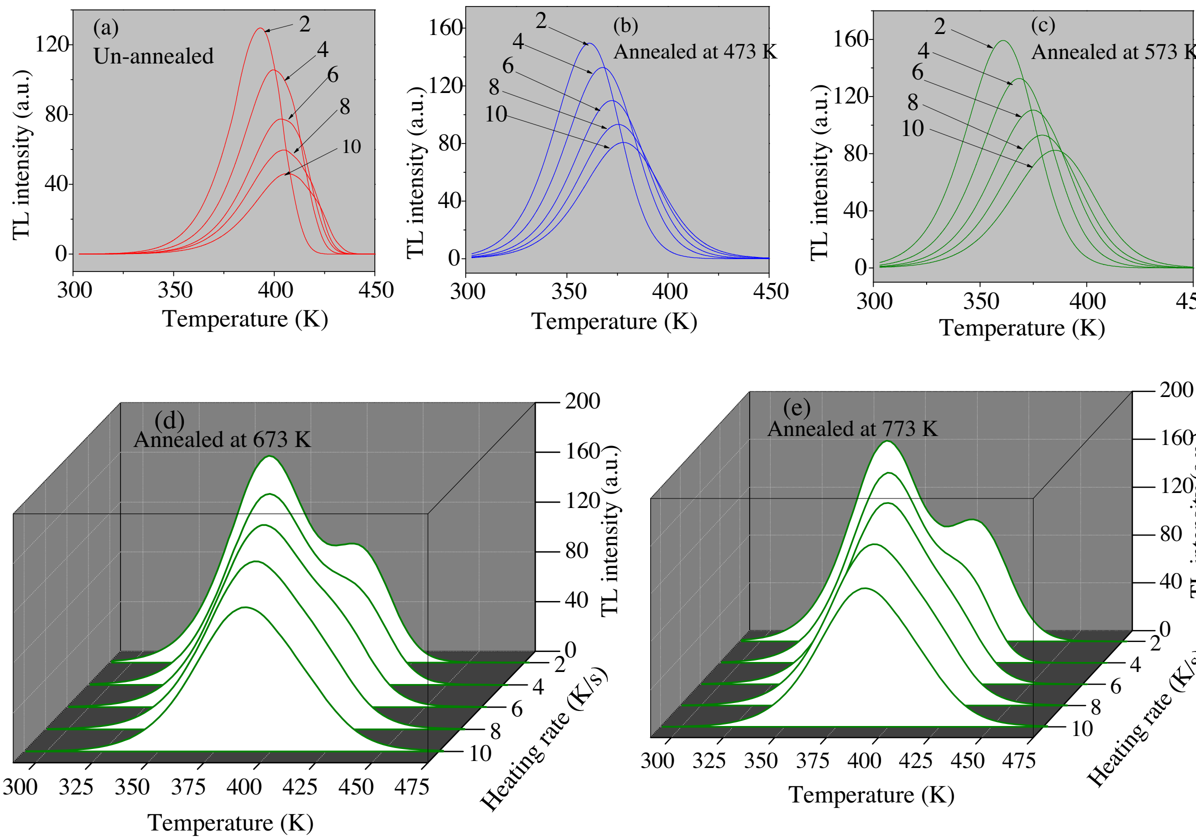

Fig. 1. Experimental TL glow curves of (a) un-annealed and (b–e) annealed samples.

crusher, and then ground in ceramic mill. Fine powder so obtained was micro-grain in nature and seemed to be blackish brown color. The samples were then divided into four parts. Each part was annealed at temperatures: 473, 573, 673 and 773 K for 1 h and then cooled to room temperature naturally. Taking 10 mg sample for each TL measurement, all type of annealed samples were exposed by X-ray source under operating voltage 35 KV at 15 mA for 20 min. TL was recorded with TL reader (NUCLEONIX-TL 1009I) at different heating rates 2, 4, 6, 8 and 10 K/s under the same linear temperature profile from 290 K to maximum temperature of 480 K. In TL measurement quartz filter is used in front of the photomultiplier tube that allowed to pass only visible light and absorbed infrared light.

3. Result and discussion

The fine powder of biotite obtained by grounding is crystalline in nature [6]. Fig. 1(a) shows the previously reported TL glow curves of un-annealed biotite [6] and Fig. 1(b–e) are the TL glow curves of different annealed samples recorded at 2, 4, 6, 8 and 10 K/s heating rate respectively. Activation energy, order of kinetic and frequency factor were calculated for each heating rate by Computerized Glow Curve Deconvolution (CGCD) technique and reported in Table 1. In this method, TL glow curves have simulated for each peak by using Kitis general order equation [7]:

$$I(T) = I_m b^{b/b-1} \exp\left(\frac{E}{kT}\frac{T-T_m}{T_m}\right) \times \left[(b-1)(1-\Delta)\frac{T^2}{T_m^2}\exp\left(\frac{E}{kT}\frac{T-T_m}{T_m}\right)+Z_m\right]^{-(b/b-1)} \quad (1)$$

with $\Delta = 2kT/E$, $\Delta_m = 2kT_m/E$, $Z_m = 1+(b-1)\Delta_m$. Where I is TL intensity, E (eV) is activation energy, I_m is peak maximum intensity, T_m (K) is peak maximum temperature, b is order of kinetics, k is Boltzmann's constant and T is absolute temperature. For each peak the goodness of fit is tested by the Figure of Merit (FOM) which is expressed as:

$$\mathrm{FOM} = \sum \frac{|Y_{\mathrm{Expt}} - Y_{\mathrm{Fit}}|}{Y_{\mathrm{Fit}}} \quad (2)$$

where Y_{Expt} is the experimental glow curve, Y_{Fit} is the fitted glow curve [8]. All deconvoluted glow curves are accepted when their FOM values are lower than 2%. The frequency factor was calculated by using the following Eq. (3), which was derived from the general order equation [9]:

$$s = \frac{\beta E}{kT_m^2(1+(2kT_m(b-1)/E))}\exp\left(\frac{E}{kT_m}\right) \quad (3)$$

where β the heating rate. In this paper all the glow curves were simulated by using OriginPro 8 software specially modified for CGCD. Fig. 2(a–c) shows three typical glow curves deconvoluted peak along with their residuals of the fitting process. The variations of peak maximum temperature, FWHM and peak integral with heating rate are shown in Fig. 3(a–c) for un-annealed and different annealed sample respectively. In Fig. 3(a), variation of peak maximum temperature for simulated un-quenched glow curve as a function of heating rate are also shown. The peak maximum temperatures of simulated un-quenched glow curve are considered from our previously reported work [6]. The behavior of peak maximum temperature as a function of heating rate indicates that there is a temperature lag at higher heating rate. Moreover, the variation of FWHM and peak integral as a function of heating rate shows that as heating rate increases, the glow peaks are intended to influence by thermal quenching. Further, a significant difference in the affect of thermal quenching was observed between un-annealed and annealed samples.