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Analytical investigations of thermoluminescence glow curve on quartz for luminescence dating

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HIGHLIGHTS

- We studied the physical characteristics of the separated TL glow peaks on quartz.
- The kinetic parameters of each separated glow peak are evaluated by a CGCD method.
- The separated peaks were bleached with two or three exponential decays.
- The dose responses for the separated peaks showed a similar growth curve.

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ABSTRACT

Investigations of bleaching and thermoluminescence (TL) response to radiation dose of quartz are importance in luminescence dating. Although such research has been extensively carried out for various types of quartz, most work was performed on the basis of TL intensity integrated for a particular temperature range on the glow curve, without any peak separation. In this study we investigated bleaching by a blue light stimulation and radiation dose behaviour for separated TL glow peaks of quartz, which are thermally stable, by using the computerized glow curve deconvolution (CGCD) method combined with the T_m–T_{stop} method. The T_m–T_{stop} method indicates that the glow curve of quartz is the superposition of at least seven components (P1–P7) in the temperature range between room temperature and 450 °C. A bleaching experiment for four thermally stable glow peaks (P4–P7) using a blue light stimulation revealed that the bleaching rate of peak P4 exhibits three different exponential decays, whereas the peaks P5, P6 and P7 are bleached with two different exponential decays. After bleaching of 12 h, the TL intensity of peaks P4, P5, P6 and P7 were reduced to approximately 6%, 16%, 26% and 68% of the initial value, respectively. Additionally, in a study of the radiation dose response of the four thermally stable glow peaks, all peaks have a similar pattern, which are well fitted by a single saturating exponential function.

1. Introduction

Controlled measurement of the intensity of the luminescence signal from many crystals can provide a means of determining the time which has elapsed since the luminescence was last drained from the sample, and the age of the sample. If this technique is focused on the sediment dating, one of the necessary criteria is to investigate the bleaching of the sample. In the case of quartz, the material most commonly used in luminescence dating, Spooner et al. (1988) carried out quantitative bleaching studies using selective wavelengths in the visible photons and found that the bleaching sensitivity of the TL peaks increased with decreasing wavelength. Later, it was reported that there exist two main TL peaks in the 300–400 °C region; the peak at 325 °C is designated as the rapidly bleaching peak (RBP) and the other, at 375 °C, is called the slowly bleaching peak (SBP) (Franklin, 1997). Besides the bleaching study, investigation of the luminescence response to radiation dose can also improve the technique because luminescence dating is to relate luminescence intensity to radiation dose by irradiating the sample in the laboratory, associated with determination of the equivalent dose. Although such researches have been extensively carried out for various types of quartz (Lai and Murray

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(2006) and Jain et al. (2007) are two examples), most work was performed on the basis of TL intensity integrated for a particular temperature range on the glow curve, without any peak separation. However, it is recognized that each TL glow peak of the quartz sample is generally composed of the sum of overlapping peaks (Pagonis et al., 2002; Yazici and Topaksu, 2003). The TL glow peaks can be separated using various methods, such as the repeated initial rise (RIR), variable heating rate (VHR), computerized glow curve deconvolution (CGCD), and peak shape (PS), which have originally been developed to determine the main trap parameters of TL glow peaks. Among these methods, in the case where the glow curve consists of several overlapping peaks, as for quartz, the CGCD method is appropriate, as reviewed by Horowitz and Yossian (1995).

The aim of this work is to investigate bleaching by a blue light stimulation and radiation dose behaviour for separated TL peaks of quartz by using the CGCD method.

2. Sample and equipment

A quartz sample was prepared from "acid washed sand" supplied by BDH Ltd. The quartz was treated with concentrated HF for 1 h, followed by washing with 10% HCl and distilled water. Then the quartz was sieved to select grains 90–125 μm in size. The absence of feldspar contamination was confirmed by observing infrared stimulated luminescence following a beta dose of 50 Gy.

All TL measurements were made with a linear heating rate of 5 °Cs^{-1} in a N_2 atmosphere using an automated Riso TL/OSL system (Model TL/OSL-DA-15) installed at the Central Laboratory of Kangwon National University. Luminescence detection was achieved by an EMI 9235QA photomultiplier tube using a Hoya U340 filter with which the wavelength peaked at 280–380 nm. Irradiation of the sample was carried out with a $^{90}Sr/^{90}Y$ beta source delivering about 0.13 Gys^{-1}, which was calibrated using quartz. The bleaching experiment was conducted using blue light (λ = ~470 nm) emitting diodes with a power of 28 mWcm^{-2} at the sample position provided by the Riso TL/OSL system.

3. Experimental methods and results

3.1. Peak separation

The TL glow curve of quartz sample after beta irradiation of 100 Gy was measured up to 450 °C (Fig. 1(a)). Five peaks are dominated at about 100 °C, 130 °C, 220 °C, 280 °C and 350 °C, which is typical of quartz (Pagonis et al., 2002). These TL glow curves generally consist of several overlapping peaks and can be readily separated by using a computerized glow curve deconvolution (CGCD) method. However, in the analysis of complex glow curves by the CGCD method, knowledge of the number of glow peaks in the glow curve is required because the results obtained using this method highly relies upon the input parameters used in the deconvolution program. In this study, the T_m–T_{stop} method (McKeever, 1980) was used to identify how many glow peaks exist in the TL glow curve. The quartz samples are irradiated to 30 Gy at room temperature. After the samples are heated to a temperature defined as T_{stop}, they are cooled to room temperature. The quartz samples are then re-heated to record the remaining TL glow curve up to 450 °C. This process is repeated several times on the same annealed/irradiated sample at different T_{stop} values with a 5 °C interval. By this process, we found that there are apparently seven plateau regions, which indicate that the TL glow curve consists of at least seven glow peaks (Fig. 2).

Before the deconvolution of the glow curve, we investigated the kinetic order using the dose dependence effect on the peak

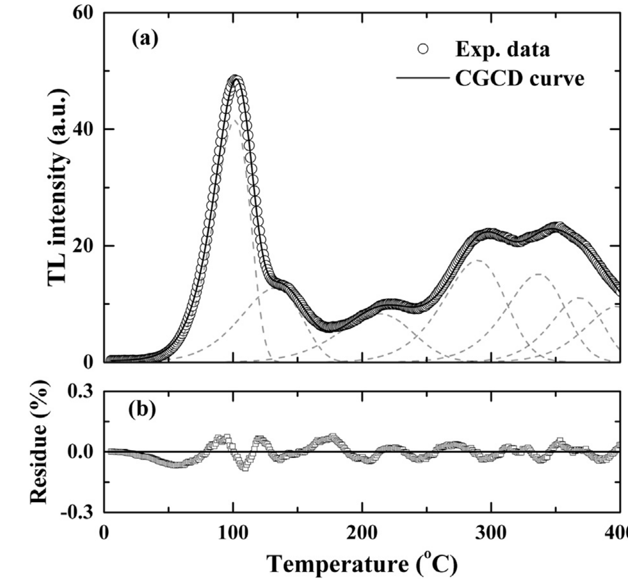

Fig. 1. (a) Experimental glow curve and separated peaks using the CGCD method and (b) residue of fitted curve.

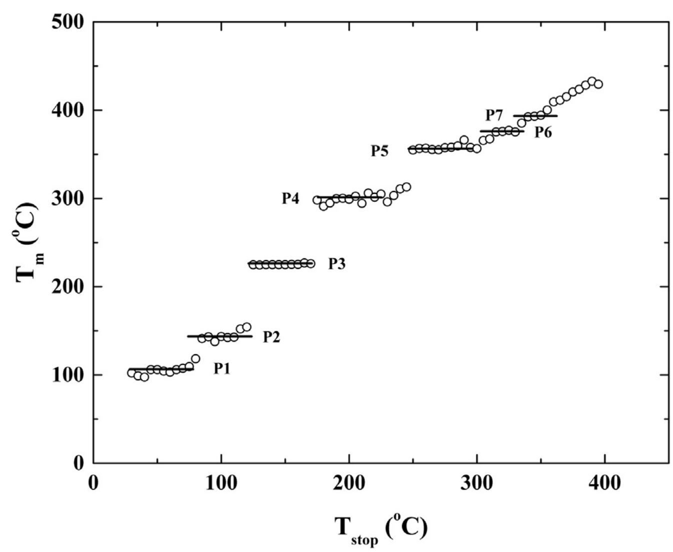

Fig. 2. Plot of first maximum temperatures (T_m) of remaining TL glow peaks versus each temperature T_{stop} following the T_m–T_{stop} procedure.

positions (Yazici and Topaksu, 2003). Some of the selected glow curves after different dose irradiations are shown in Fig. 3. As represented in Fig. 3, the peak positions of the 1st and 2nd (100 °C and 130 °C) peaks were not changed but the peak positions of the 3rd–5th (220 °C, 280 °C and 350 °C) peaks were clearly shifted to the lower temperature side with increasing radiation doses. This suggests that the 1st and 2nd peaks follow the first order kinetics, and the 3rd–5th peaks are non-first order kinetics.

With this information, analyses were carried out to obtain the kinetic parameters of the individual peaks using the CGCD method with a nonlinear fitting of the glow peaks following the first and the general order kinetic model (Kitis et al., 1998). The first order kinetics is approximated by the following expression: