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Thermoluminescence studies of Si^{+8} ion irradiated kyanite

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Abstract

Thermoluminescence (TL) of natural kyanite single crystals bombarded with 100 MeV Si^{+8} ions with fluences in the range 1×10^{11}–5×10^{13} ions/cm^2 has been studied at room temperature (RT). Two TL glows, a medium one at $\sim$ 445 K and another intense one at $\sim$ 550 K are recorded in single crystals of kyanite. However, in the case of pelletized samples, similar TL glows but with peaks at $\sim$ 475 and 615 K, respectively, are recorded at a warming rate of 20 K/min. It is found that as the fluence of Si^{+8} ion increases, the TL intensity increases. It is also found that the characteristic TL glow peaks appear at higher temperature side in pelletized kyanite than those in crystalline ones, however, the glow peak temperatures remain steady in a given system irrespective of the ion dose. The enhancement in TL intensity and shifting of TL glow peaks to higher temperature side in pelletized kyanite samples are attributed to the particle nature of the phosphor and/or pressure-induced defects in the phosphor.

Keywords: Thermoluminescence; Kyanite; Swift heavy ion; Glow curve

1. Introduction

The creation of defects in alkali halides under various types of radiations has been extensively studied during the past few decades. In addition, attempts have been made to establish a correlation of the damage coefficients among different types of radiations. In the case of ions, the spatial distribution of the energy deposition is not homogeneous, but each individual ion deposits its energy with an approximately $1/r^2$ dependence on the radial distance from the trajectory. Such a dose gradient could have a strong influence on the defect creation mechanism and on the nature of the damage. The creation of damage tracks by swift heavy ions (SHI) in matter in the early stage might be due to the perturbation of the electronic system after the passage of ions ($\sim$ 10^{-17}–10^{-13} s). A large part of the projectile energy is transferred to target electrons. The subsequent kinetic electron emission from the solid surface is an important probe for the interpretation of SHI with matter (Rothard et al., 1997).

Kyanite, an aluminum silicate mineral with chemical formula Al_2SiO_5, crystallizes in triclinic. These crystals are usually transparent to translucent, blue in color and generally contain impurities such as iron and potassium. They are useful for high-temperature applications because of their low thermal conductivity. A good amount of work has been done on γ-irradiated aluminum silicates, especially on topaz and feldspars (Mittani et al., 1999; Souza et al., 2000, 2001). Literature survey, on the other hand, revealed only a limited work on kyanite due to heavy ions (Wang et al., 1997). In the present work, thermoluminescence of SHI irradiated kyanite have been studied and the results obtained are presented.

2. Experimental

Kyanite single crystals each of about 1 mm thickness and $\sim$ 45 mm^2 area are obtained by cleaving the long-thin block of natural kyanite procured from Indian Bureau of Mines. Also, powder form of kyanite with grain size in the range

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45–150 μm are prepared using pestle and mortar. Pellets of ∼ 1 mm thickness and 6 mm diameter are prepared using polyvinyl alcohol as a binder and applying a pressure of 6 t/ram of 6 mm diameter, using an home made pelletizer at RT. These samples are irradiated with 100 MeV Si^{+8} ions with fluences in the range 1×10^{11}–5×10^{13} ions/cm^2 from 15UD pelletron at Nuclear Science Center, New Delhi. The detailed experimental arrangement for SHI irradiation are described elsewhere (Singh et al., 2001). After irradiation, the TL studies are carried out with a home made TL set up described elsewhere (Lakshminarasappa, 1990).

3. Results and discussion

The values of thermoluminescence intensity and the corresponding temperature are calculated from the experimentally recorded glow curves and redrawn to the actual scale. Fig. 1 shows the TL glow curves of kyanite single crystals irradiated with 100 MeV Si^{+8} ions with fluences in the range 1×10^{11}–5×10^{13} ions/cm^2. Two TL glows, one at ∼ 445 K and another one at ∼ 550 K are observed in all the single crystals of kyanite studied in the present work. Fig. 2 shows the TL glow curves of pelletized kyanite irradiated for the same dose. Two TL glows with peaks at ∼ 475 and 615 K are observed when the phosphor is warmed at 20 K/min. It is found that the TL intensity at both TL glow peaks in both crystalline and pelletized kyanite increases almost linearly with increase of Si^{+8} ion fluence and the results are shown in Fig. 3. Further, the temperature at the glow peaks in pelletized samples are found to be shifted towards higher temperature side when compared to those of crystalline ones. This may be attributed to inter-particle spacing in the case of pelletized samples. Also, the TL intensity in pelletized kyanite is found to be higher when compared to that in crystalline form. This might be due to physical nature, structure of the sample and/or pressure-induced defects in the phosphor. The higher temperature glow peak (615 K) in the present studies might be due to atomic displacements or by thermal spike formation due to radiation damage. Also, during ion bombardment, in addition to displacements of atoms/ions other consequences involving the coordination behavior of atoms may take place. These are known as thermal spikes resulting from sudden heating during 10^{-12}–10^{-10} s. Also, it is found that the effect of SHI irradiation on TL characteristic of kyanite crystals are similar to that of γ-irradiated ones (Lakshminarasappa et al., 2000).

4. Conclusions

A pair of characteristic TL glows are observed in both crystalline as well as pelletized kyanite samples irradiated with Si^{+8} ions. The TL intensity in pelletized samples is found to be enhanced when compared to crystalline ones. The glow peak temperatures in pelletized samples are found to be shifted towards higher temperature side when compared to those in crystalline ones. However, the glow

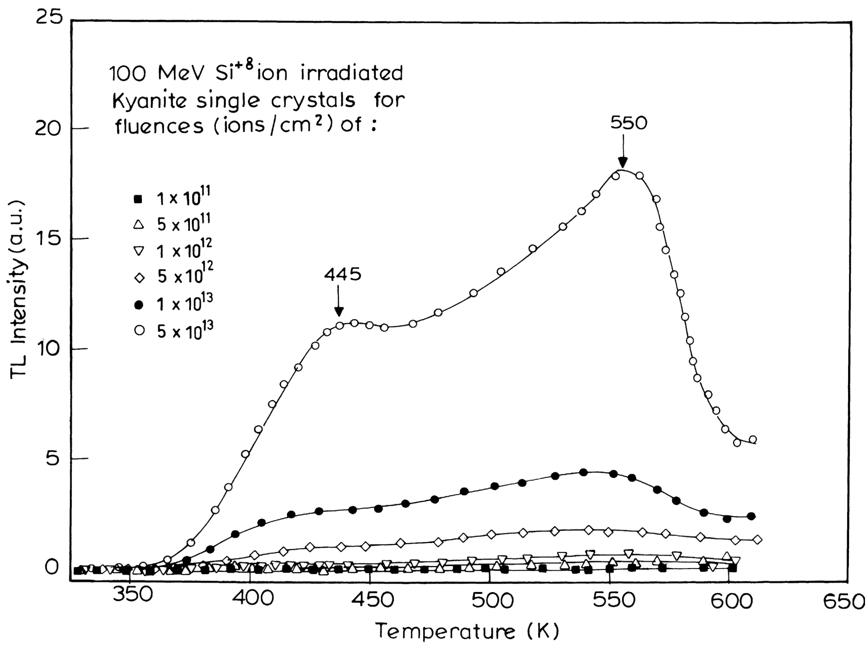

Fig. 1. Thermoluminescence glow curves of Si^{+8} ion irradiated crystalline kyanite.

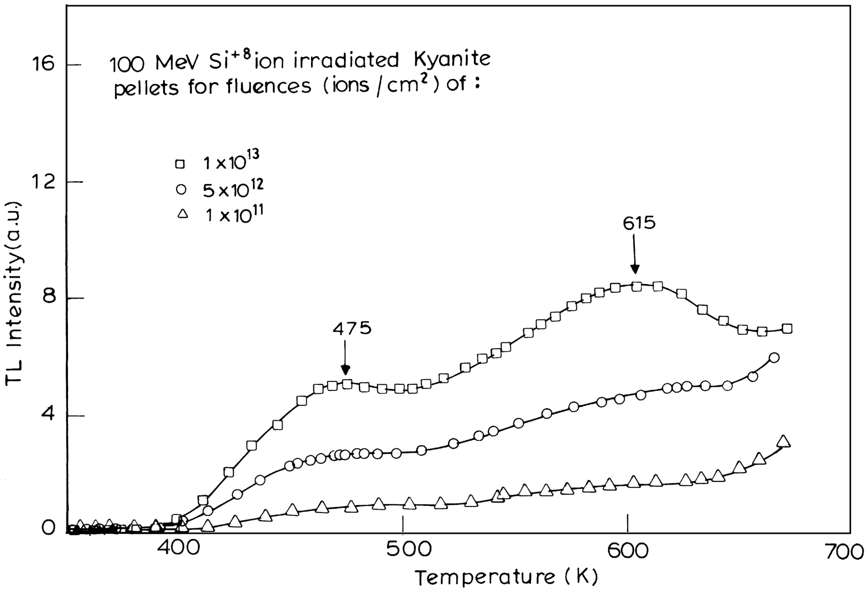

Fig. 2. Thermoluminescence glow curves of Si^{+8} ion irradiated pelletized kyanite.

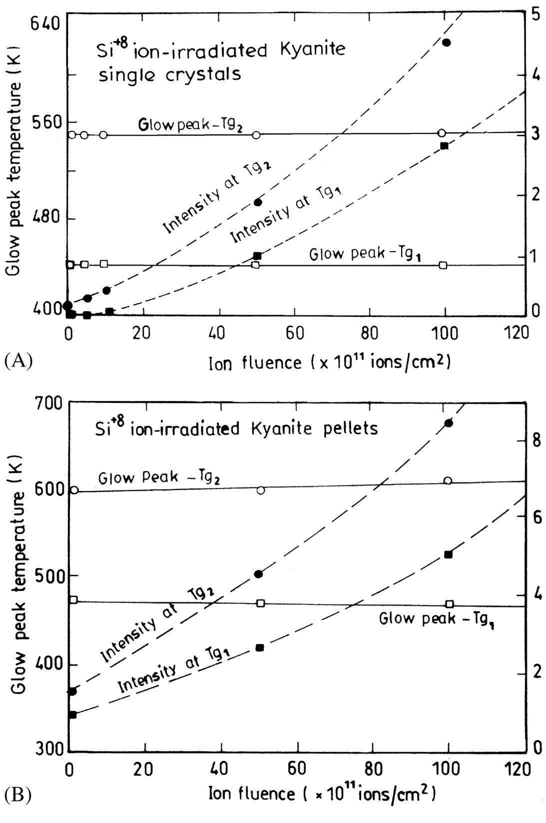

Fig. 3. Variation of TL glow peak temperature and TL glow peak intensity as a function of ion fluence in Si^{+8} ion irradiated (A) crystalline and (B) pelletized kyanite.

peak temperature in each of the above system remains steady in the present work. The shifting of glow peak temperature to higher temperature side and enhancement in TL intensity in pelletized samples may be attributed to particle nature of the phosphor and/or pressure-induced defects in the phosphor.

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