Effect of pre-irradiation deformation on thermoluminescence of divalent impurity doped alkali halide crystals

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The effect of pre-irradiation deformation on the thermoluminescence (TL) of alkali halide crystals has been reported. The pre-irradiation deformation causes increase in the thermoluminescence intensity corresponding to both the TL glow peaks of alkali halide crystals. The dependence of TL intensity corresponding to first and second TL peaks on pre-irradiation deformation follows the relations \( \frac{I_0}{I} = f(\xi) \) and \( \frac{I_0}{I} = f(\xi) \), respectively. It is shown that the dislocation debris created during pre-irradiation deforms the existing traps, and/or causes a redistribution of electrons or holes among these traps due to the passage of dislocations in the vicinity of the traps. This results increase in the probability of the formation of stable F-centres. Consequently, for the same radiation doses given to the crystals, the density of F-centres and thereby the TL intensity increases with the pre-irradiation deformation of alkali halide crystals.

1 Introduction

In studies of the effect of mechanical stress in solids, generally the attention is concentrated on the lattice response to loading. Less consideration is given to the electron sub-system response, making it unclear whether mechanical loading can result in electron transition. Information on electron excitation may be obtained by studies of electron emission, deformation luminescence, deformation bleaching, and deformation-generated coloration of crystals. The study of the phenomena initiated by mechanical stress on solids is important, since it yields information about the mechanisms of deformation of solids.

The two cases namely the deformation prior to irradiation and deformation subsequent to irradiation are related to one another but differ slightly. Deformation prior to irradiation modifies the existing traps and/or creates new traps which then can be filled during irradiation. However, the deformation subsequent to irradiation modifies the existing traps, creates new but unfilled traps, and/or causes a redistribution of trapped electrons or holes among these traps due to the passage of dislocations in the vicinity of the traps.

In the past the increase in TL intensity with pre-irradiation deformation of crystals has been reported from time to time, but no clear understanding has been achieved. In this connection, the present paper reports the effect of pre-irradiation deformation on the TL of alkali halide crystals.

2 Experimental Details

Pure and Ba\(^{2+}\), Sr\(^{2+}\) and Ca\(^{2+}\) doped NaCl, KCl, KBr and KI crystals were grown from the slow cooling of their melt. The size of the crystals used was 2 x 2 x 2 mm\(^3\). Before irradiation, crystals were annealed at 400°C for 4 hr. Crystals were deformed along their (100) direction using a tensile tester (Model 1.3 KML, Ahmedabad) at a strain rate 3.3 x 10\(^{-2}\) cm/sec. The \(\gamma\)-irradiation deformation on TL glow curve, crystals were deformed at different levels of strain, then they were \(\gamma\)-irradiated, and the TL output was recorded by using a TL unit.

3 Results and Discussion

Fig. 1 shows the TL glow curves of under-formed pure NaCl, NaBr, KCl, KBr and KI crystals. It is seen that two peaks occur in the TL glow curves, which lie at 115 and 200°C, 105 and 165°C, 120 and 180°C, 105 and 165°C, and 140 and 205°C, for NaCl, NaBr, KCl, KBr and KI crystals, respectively. Similar curves were also obtained for Ba, Sr and Ca doped NaCl, NaBr, KCl, KBr and KI crystals, where there is only a difference in the
TL intensity. It is found that the glow peak temperatures do not change significantly with the inclusion of dopants. The TL intensity was found to increase with the concentration of dopants up to 1000 ppm in all the crystals.

Figs 2 to 5 also show the TL glow curves of undoped and impurity doped NaCl crystals having different values of the pre-irradiation deformation of the crystals. It is seen that no significant change occurs in the glow peak temperature due to the pre-irradiation deformation.

Fig. 1 — TL glow curves of undeformed pure NaCl, NaBr, KCl, KBr and KI crystals

Fig. 2 — Effects of pre-irradiation deformation on the TL glow curves of NaCl crystals (γ-dose = 3000 Gy)
Fig. 3 — Effect of pre-irradiation deformation on the TL glow curves of NaCl:Ba (1000 ppm) crystals (γ-dose = 300 Gy)

Fig. 4 — Effect of pre-irradiation deformation on the TL glow curves of NaCl:Sr (1000 ppm) crystals (γ-dose = 300 Gy)
However, the intensities of both peaks of the TL glow curve increase with the deformation. Similar results were also found for pure and impurity doped NaBr, KCl, KBr and KI crystals.

Fig 6 shows the plot of log $I_m$ versus strain $\varepsilon$ and log $I_m$ versus strain $\varepsilon$ for undoped and Ba$^{2+}$, Sr$^{2+}$ and Ca$^{2+}$ doped NaCl crystals. It is seen that for all these crystals the plots of log $I_m$ versus strain are straight lines with positive slopes. This fact indicates that the dependence of $I_m$ and $I_m$ on strain $\varepsilon$ should follow the relation

\begin{equation}
I_m = I_{m0} \exp (\xi \varepsilon) \quad \ldots (1)
\end{equation}

\begin{equation}
I_m = I_{m0} \exp (\xi' \varepsilon) \quad \ldots (2)
\end{equation}

where $I_{m0}$ and $I_{m0}$ are the values of the intensity of first and second TL peaks for the crystals deformed by strain $\varepsilon$ prior to irradiation, $I_{m0}$ and $I_{m0}$ are the values of the TL intensity, respectively, for first and second TL peaks for undeformed crystals and $\xi$ and $\xi'$ are constants.

Similar dependence of $I_m$ on $\varepsilon$ was also found for undoped and Ba$^{2+}$, Sr$^{2+}$ and Ca$^{2+}$ doped NaBr, KCl, KBr and KI crystals.

The values of $\varepsilon$ and $\varepsilon'$ were determined from the In$I_{m0}$ versus $\varepsilon$ plot and they are shown in Table 1.

The TL of pure and impurity doped alkali halide crystals consists of two glow peaks, one at lower temperature and the other at higher temperature. The dipoles in the dislocation free regions are responsible for the low

<table>
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<tr>
<th>Crystals</th>
<th>Impurity</th>
<th>Value of $I_{m0}$ (Arb. units)</th>
<th>Value of $I_{m0}$ (Arb. units)</th>
<th>Value of $\xi$</th>
<th>Value of $\xi'$</th>
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temperature TL peak and the higher temperature TL peak is due to the combination of dipoles with a negative ion vacancy, the complex being situated in the dislocation regions. The intensities of both the TL peaks have been found to depend directly on the density of colour centres.

During the growth as well as deformation of alkali halide crystals some of negative ions leave their original sites and occupy interstitial positions. When the crystals having negative ion vacancies are irradiated with γ-rays or x-rays, the electrons jump from the valence band to the conduction band, whereby most of the conduction electrons fall back to the valence band, however, some of them are trapped in negative ion vacancies and give rise to the formation of F-centres. If the dislocation debris created during prior deformation of crystals trap the interstitials, then the probability of back reaction i.e. recombination between interstitials and negative ion vacancies decreases and the probability of formation of stable F-centre increases. Consequently, for the same radiation dose given to the crystals, the density of F-centre and thereby the TL intensity may increase with pre-deformation of the crystals. On the other hand, if the dislocation debris created during plastic deformation trap free electrons generated during irradiation of the crystals, then they promote back reaction i.e. the recombination of interstitials with vacancies. In this case, for the same radiation dose given to the crystals, the density of F-centres and thereby the TL intensity may decrease with the pre-irradiation deformation of the crystals.

In undoped and impurity doped alkali halide crystals, the TL intensity is found to increase with the pre-irradiation deformation of crystals. The fact indicates that in this case, the probability of back reaction decreases with the pre-irradiation deformation of the crystals and hence the density of F-centres and thereby the TL intensity increases with pre-irradiation deformation of the crystals.
References