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Effect of pre-irradiation deformation on thermoluminescence of Cu^{++} doped NaCl crystals

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ABSTRACT

In the present study the effect of pre-irradiation deformation on the thermoluminescence (TL) of γ-irradiated undoped and Cu^{++} doped NaCl crystals for different impurity concentrations, radiation doses etc. have been studied. Two peaks at 392° K and 465°K respectively are observed in TL glow curves of pre-irradiation deformed undoped and Cu^{++} doped NaCl crystals. The intensities of both the peaks in TL glow curves increases linearly with increasing pre-irradiation deformation of the pure and Cu^{++} doped NaCl crystals. It is found that increase in the TL peak-II with strain is higher as compared to that of TL peak-I. The temperature Tm_1 and Tm_2 corresponding to the first and second peaks in TL glow curves respectively, do not change significantly with the pre-irradiation deformation of the crystals.

Key words: Deformation, γ- irradiation, thermoluminescence, NaCl crystals.

INTRODUCTION

The plastic deformation has considerable influence on the electrical, optical, mechanical and other properties of solids. It has been found that the plastic deformation affects considerably the thermoluminescence of crystals. The deformation of materials can arise out of the operations such as crushing, grinding, packing, palletizing etc. The different processes which may arise out of such operations can be micro-cracking , formation and annihilation of crystal dislocations, inter granular gliding, rupturing, pressure twinning and so on.

Thermoluminescence are related to imperfection impurities and defects in crystals. It could be expected therefore, that the application of high pressure on a sample produces. New defects would influence the TL properties of the sample. So far as the effect of deformation on TL is concerned, two types of measurements can be performed : Firstly, the effect of pre-irradiation deformation TL and secondly, the effect of post-irradiation deformation on TL. In the case of pre-irradiation deformation, the specimen is initially deformed and then exposed to any fast ionising radiation such as γ-rays. However in the case of post-irradiation deformation, the specimen is initially exposed to radiations and then it is deformed. Both the cases affect the TL in different manner's. Thermoluminescence and Mechanoluminescence (ML) properties of γ-irradiated Dy activated potassium and magnesium mixed sulphate have been studied (1). Two distinct peaks are observed in the TL glow curve. TL intensities of both peaks decrease after deforming the irradiated samples. It is suggested that the recombination of electron with the free radicals (anion radicals produced by γ-irradiation) released from the traps during the thermal excitation is responsible for the luminescence in this system. The effect of pre-heat treatment on the thermoluminescence of Xirradiated NaCl crystals containing yttrium has been studied in some details[2]. Pre-heat treatment in these crystals caused the shifting of TL glow peaks to high temperature side and an enhancement in TL intensity. These changes are attributed to the creation of large number of luminescent centers due to pre-heat treatments, influence of internal fields of these centers and shifting of energy levels of various traps responsible for TL. In order to have a better idea of the interaction of the defect centres produced by gamma-irradiation with dislocation in the process of deformation destruction mechanoluminescence and thermoluminescence of gamma-irradiated $CaSO_4$:Dy phosphors have been investigated[3]. The total light output, i.e. integrated ML intensity, increases with concentration of dopant, strain rate and with irradiation doses. The TL glow curves of $CaSO_4$:Dy phosphors at different concentrations of dopant and irradiation doses were also recorded. Studies on the influence of post-irradiated annealing on the ML $CaSO_4$:Dy show that with the removal of the TL dosimetric peak, the intensity decreases markedly.

In this study we have discussed only pre-irradiation deformation. The pre-irradiation deformation modifies the traps and/or creates new traps which can then be filled during irradiation.The pre-irradiation deformation causes increase in the intensity of existing TL peaks as well as in the intensity of the deformation generated new TL peak. However, when the extent of back reaction increases with deformation, then the intensity of the associated TL peaks decreases with increasing pre-irradiation deformation of the crystals[4,5-9]. To date least attention has been paid to the systematic investigation of the effect of pre-irradiation deformation on the TL of NaCl : Cu^{++} crystals. The present investigation reports the effect of pre-irradiation deformation on the TL of Cu doped NaCl crystals.

EXPERIMENTAL

The experimental setup for the study of TL glow curves consists of a photomultiplier tube, a high voltage unit, an amplifier, a temperature programmer and a strip chart recorder. The samples used in the present investigation were irradiated with γ-rays using a ^{60}Co source. The divalent impurity (Cu^{++}) doped NaCl single crystals were grown by the method of slow cooling of melt.

For the TL measurements, the crystals of small size $4 \times 2 \times 2$ mm^3 were cleaved from the central lower part of the large crystal. Before irradiation the crystals were annealed at 450°C for 4 hours. The crystals were deformed for different level of strain ($\in$) along their (100) direction by using tensile tester model 1.3 DKMI, Ahemadabad, where the strain rate was 3.3×10^{-2} cm/sec.

In the present investigation, the TL glow curves of pre-deformed γ-irradiated pure and Cu^{++} impurity doped NaCl crystals were recorded. For measuring the effect of pre-irradiation deformation on the TL intensity of pure and impurity doped NaCl crystals, the crystals were deformed prior to irradiation by different levels of strain ($\in$) and then exposed to γ-dose and finally the TL glow curves were recorded.

RESULTS

Fig 1. shows the TL glow curves of pure NaCl single crystals having different value of pre-irradiation deformation of the crystals at g-dose = 2000 Gy. It is observed that pure NaCl crystals show two prominent peaks at 393°K and 464°K respectively. It has been found that no significant change occurs in the temperature corresponding to the peak of glow curves due to the pre-irradiation deformation of the crystals. However, the intensity of first and second peaks of the TL glow curve increases with the pre-irradiation deformation of the crystals.

Fig. 2 shows the TL glow curves of NaCl:Cu^{++} (1000 ppm.) single crystals having different value of pre-irradiation deformation of the crystals. It is observed that no significant change occurs in the temperature corresponding to the peak of glow curves due to the pre-irradiation deformation of the crystals.

Fig. 3 (a, b) shows that the plot of log Im_1 & Im_2 versus strain ($\in$) for pure NaCl single crystals for different value of g-dose. The plot of log Im_1 and Im_2 versus strain ($\in$) is a straight time with positive slope.

Fig. 4 (a, b) shows that the plot of log Im_1 and Im_2 versus strain for NaCl:Cu (1000 ppm.) single crystals for different values of g-dose. The plot of log Im_1 and Im_2 versus strain ($\in$) are straight line with positive slopes.

Fig. 5 shows that as the strain rate increases, the total TL intensity of NaCl pure and NaCl:Cu (1000 ppm.) crystals also increases.

DISCUSSION

Deformation results in the production of vacancies and other debris due to dislocation interactions. The defects created by dislocations may enhance the F-centre yield by trapping interstitials i.e. by decreasing the extent of back reaction(10,11). In the crystal, where the extent of back reaction

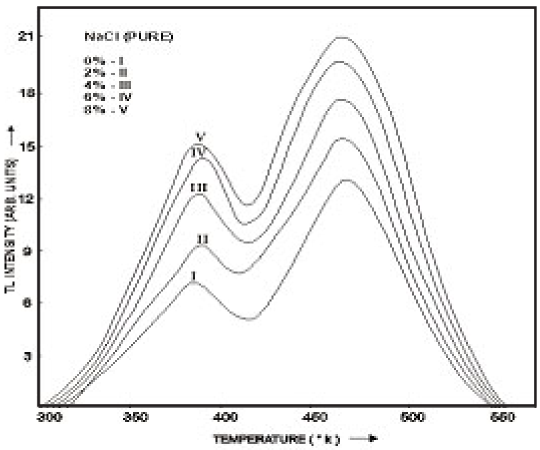

Fig. 1: Dependence on the strain of TL glow curves of NaCl pure crystals deformed prior to irradiaiton with γ-dose = 2000 Gy

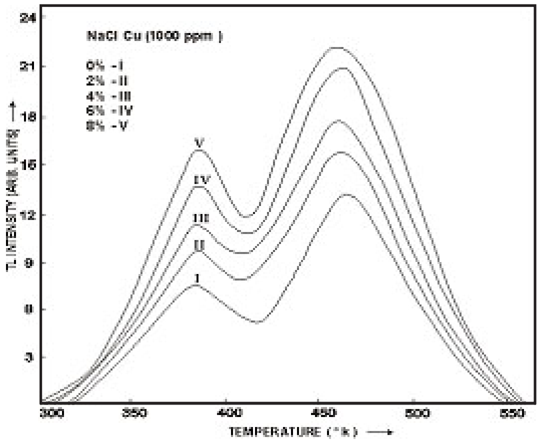

Fig. 2: Dependence on the strain of TL glow curves of NaCl:Cu (10000pm) crystals deformed prior to irradiaiton with γ-dose = 2000 Gy

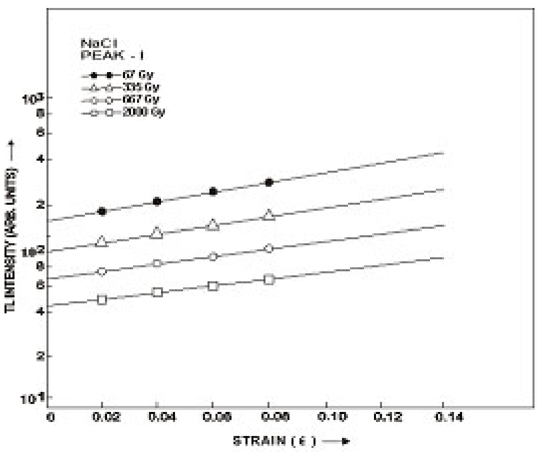

Fig. 3(a): Plot of log Im_1 versus strain ($\in$) for Nacl pure crystals with different values of γ-dose

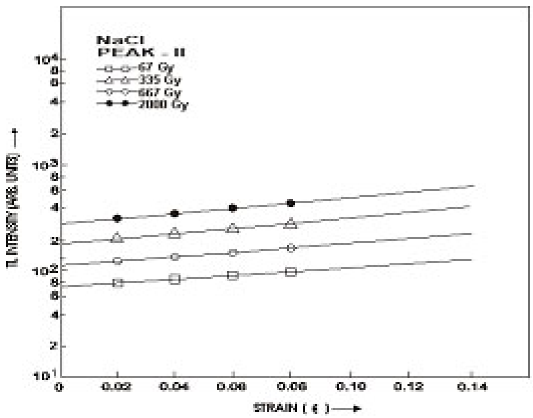

Fig. 3(b): Plot of log Im_1 versus strain ($\in$) for Nacl pure crystals with different values of γ-dose

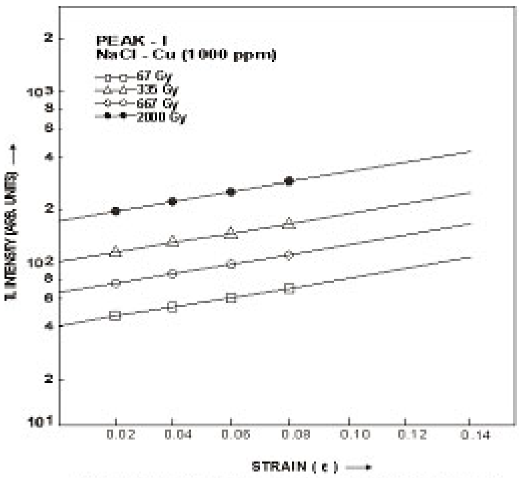

Fig. 4(a): Plot of log Im_1 versus strain (∈) for NaCl:Cu (1000 ppm) crystals with different values of γ-dose

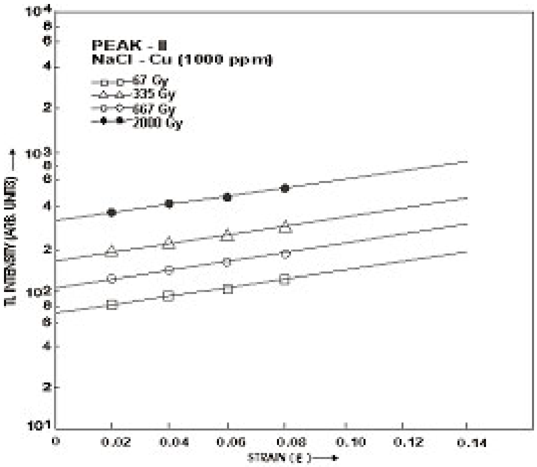

Fig. 4(b): Plot of log Im_1 versus strain (∈) for NaCl:Cu (1000 ppm) crystals with different values of γ-dose

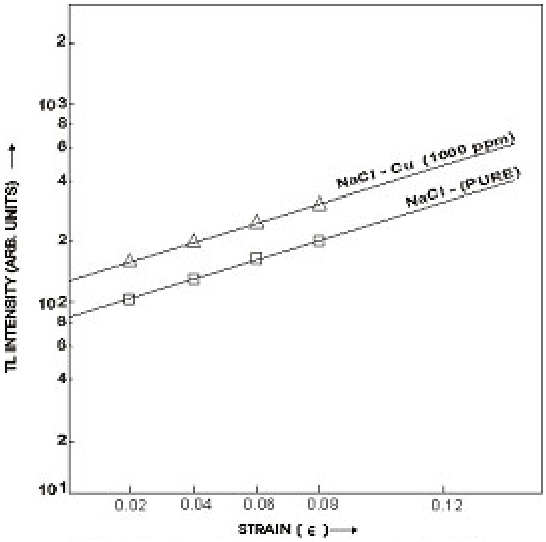

Fig. 5: Depedence of total TL intensity (I_T) versus strain (∈) with of γ-dose = 200Gy

increases with deformation, the F-centre yield may decrease with the deformation. The intensity of deformation generated TL peak should increases linearly with square of the strain of crystals. Thus it seems that if the extent of back reaction increases with pre-deformation of the crystals, then the density of colour centres increases with the pre-irradiation deformation of the crystals and consequently the intensity of TL peak-I and II increases with the pre-irradiation deformation of the crystals.

The intensity of deformation generated TL peak should increase with pre-irradiation deformation of the crystals, because of two reasons; Firstly, due to increase in the number of deformation generated compatible traps filled with electrons and secondly, due to the increase in the number of thermally stimulated electrons transferred from low energy traps to the deformation generated high energy traps.

For low dose of g-irradiation, the pre-irradiation deformation generated new TL peak occurs around 523–533°K (4). We have found that for high dose of g-irradiation, the deformation generated new TL peak does not appear in the pre-deformed crystals. The deformation generated new TL peak does not occur, because of the diffusion of interstitials in high strained region of the crystals during the strong lattice vibration produced as a result of the non-irradiative decay of excitations produced during the irradiation of crystals.

CONCLUSION

When undoped and Cu doped NaCl crystal are deformed prior to irradiation, the intensity of both TL peaks increase linearly with increase value of the strain $\in$. It is found that the rate of increase of the intensity of the TL peak-II with strain is higher than that of TL peak-I.

According to deformation dependent colouration involved traps competition model. The effect of pre-irradiation deformation on TL is attributed firstly, to the increase on decrease of F-centre yield with the pre-irradiation deformation of the crystals and secondly to the increase in the trap-competition due to increase in the number of deformation generated electron traps.

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