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Effect of post-irradiation deformation on the tl of Cu^{++} doped nacl crystals

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Abstract

The effect of post, irradiation deformation on the TL of γ-irradiated undoped and Cu++ doped NaCl crystals for different impurity concentrations and radiation doses have been studied. In the case of post-irradiation deformation, the two TL peak are found for γ-irradiated undoped and Cu^{++} doped NaCl crystals at 393°K and 464°K respectively. The intensity of both the peak decreases with increasing post-irradiation deformation of the crystals, however, the peak temperatures Tm_1 and Tm_2 do not change in the post-irradiations deformation of the crystals. There is no occurrence of post-irradiation deformation generated new TL peak in Cu^{++} doped NaCl crystals. The deformation bleaching as well as enhanced number of the compatible electron traps are responsible for the effect of post-irradiation deformation on the TL of crystals.

Keywords: Deformation, γ-irradiation, colour centres, Thermoluminescence.

INTRODUCTION

When irradiated alkali halides are heated they give rise to thermoluminescence (TL) because of the thermal annealing of colour centres with suitable radiative recombination at the emission centre. When certain materials are plastically deformed or elastically deformed or fractured is a type of mechano-luminescence (ML)[1]. Several materials such as II-IV semiconductors, MgO, certain varieties of rubber, etc. emit light, when they are plastically deformed where fracture is not required. This phenomenon of light emission induced by plastic deformation of solids is called plastico-mechanoluminescence[2]. Plastic deformation has been categorised in two different way (1) pre-irradiation deformation and (2) Post-irradiation formation of solids. In general, the light emission induced by any mechanical action on solids is known as deformation luminescence (DL). The DL in alkali halide crystals was reported for the first time by Urbach in (1930). The linear dependence of light emission on the strain rate in X-irradiated KBr, NaCl and LiF crystals was reported[3,4]. When a coloured crystal is deformed, the moving dislocation captures electrons from the F-centre during their mechanical interaction. The electrons captured by the dislocations move with them and recombine with the holes present within the interacting distance or the dislocation electrons may be captured by other traps produced during deformation of the crystals. Thus deformation bleaching and redistribution of the electrons in the traps may take place. Furthermore, a large number of vacant electrons in the traps are produced during the deformation of the crystal. In the past, the effect of post-irradiations deformation on the TL of crystals have been studied by a many workers and it has been found that generally the TL intensity decreases with post-irradiation deformation of the crystal.[5-14] The present paper reports the effect of post-irradiation deformation on the TL of pure & Cu^{++} doped NaCl crystals.

EXPERIMENTAL

The crystals used in the present investigation were grown from slow cooling of their melt method. For measuring the effect of post-irradiation deformation on the thermoluminescence (TL) intensity of pure and Cu^{++} doped NaCl crystals of small size 4 x 2 x 2 mm3 were cleaved by sharp edge knife and annealed at 450°C for four hours. The irradiated crystals were deformed from different level of strain (ε_p) along their (100) direction by using a tensile tester machine model 1:3 DKM-Ahmedabad where the strain rate 3.3 x 10-2 cm/sec. The γ-irradiated was carried out by using a $^{60}C_O$ source. For TL measurement a routine TL setup was used. The crystals were exposed to different level of γ-dose and impurity concentration was 1000 ppm of the pure and Cu^{++} doped NaCl crystals.

RESULTS

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

Fig. 2 shows the TL glow curve of NaCl : Cu (1000 ppm) single crystal having different value of post-irradiation deformation of the crystals at γ-dose = 2000 Gy. It is observed that no significant change occurs in the temperature corresponding to the peak of the glow curves due to the post irradiative deformation of the crystals.

Fig. 3(a) and 4(a) shows that the plot of log I_{m1} versus strain (ε_p) for pure NaCl and NaCl : Cu^{++} (1000 ppm) single crystals for different value of γ-dose. The plot of log I_{m1} versus strain (ε_p) is a straight line with negative slope. This fact shows that the dependence of I_{m1} on strain (ε_p) follows the relation - $I_{m1} = I^0_{m1} \exp(-\alpha\, \varepsilon_p)$. Where I^0_{m1} are the value of the intensity of first peak for undeformed crystals and I_{m1} represents the value of the TL intensity of first peak for the crystals deformed by strain (ε_p) after irradiation.

Fig. 3(b) and 4(b) shows that the plot of log I_{m2} versus strain (ε_p) for pure NaCl and NaCl : Cu^{++} (1000 ppm) single crystals for different value of γ-dose. The plot of log I_{m2} versus strain (ε_p) is a straight line with negative slope. This fact shows that the dependence of I_{m2} on strain (ε_p) follows the relation - $I_{m2} = I^0_{m2} \exp(-\alpha\ \varepsilon_p)$. Where I^0_{m2} are the value of the intensity of first peak for undeformed crystals and I_{m2} represents the value of the TL intensity of second peak for the crystals deformed by strain (ε_p) after irradiation.

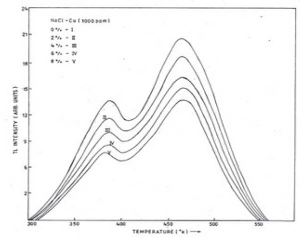

Fig.-2 Dependence on the strain of TL glow curve of NaCl:Cu (1000 ppm) crystals deformed after irradiation (γ dose = 2000).

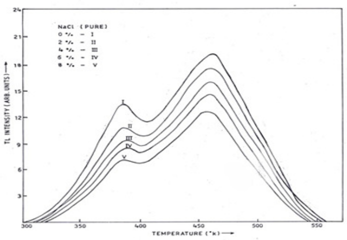

Fig.-1 Dependence on the strain of TL glow curve of NaCl pure crystals deformed after irradiation (γ dose = 2000).

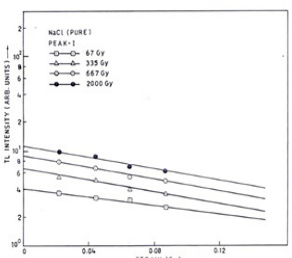

Fig.-3(a) Plot of log I_{m_1} versus strain ϵ_p for NaCl pure crystals with different values of γ-doses.

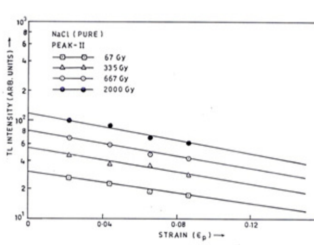

Fig.-3(b) Plot of log I_{m_2} versus strain ϵ_p for NaCl pure crystals with different values of γ-doses.

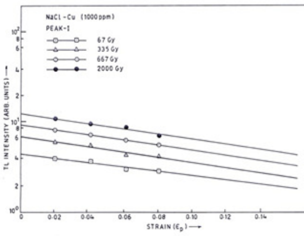

Fig.-4(a) Plot of log I_{m_1} versus Strin ϵ_p for NaCl:Cu (1000 ppm) crystals with different values of γ-doses.

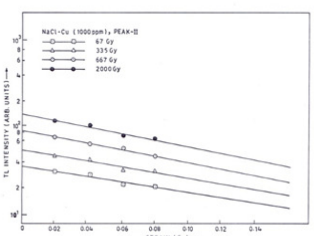

Fig.-4(b) Plot of log I_{m_2} versus Strin ϵ_p for NaCl:Cu (1000 ppm) crystals with different values of γ-doses.

DISCUSSION

Several studies have been conducted attempting to explain deformation luminescence[15]. The most comprehensive theory to date proposes a dislocation mechanism for deformation luminescence (DL). According to this theory ionizing radiation, as well as other high energy processes, dislocate electrons and ions in the regular lattice structure. Electrons are relocated into high energy electrons well known as F-centres, which colour the crystals. When the crystal is plastically deformed, the stress overcomes the F-centres and subsequently ionizing them. The electrons are then released in the conduction band and dropped into a lower level well. If an electron recombines with a luminescence centre, deformation luminescence observed.[16] According to some studies, ionizing radiation greatly amplifies photon emissions by increasing the number of F-centres within the lattice structure. The DL intensity depends on concentration of dopant, irradiation dose and mass of the load or applied pressure. It is suggested that the moving dislocation produced during the formation of crystals captured holes from hole trapped centres (like perturbed Vk centre) and the subsequent radiative recombination of he dislocation holes with electrons[17]. In alkali halide crystals, the dislocation band lies just above the ground state F-centre level where the energy gap between the bottom of the dislocation band and the ground state of an F. centre is of the order 0.10 ev.[18] When a coloured alkali halide crystals is plastically deformed, the moving dislocations may capture electrons from the colour centers and may subsequently transport the captured electrons to hole centers, deep traps and other compatible traps in the crystal. As a matter of the fact, deformation bleaching of colouration in alkali halide crystals may take place. According to the deformation bleaching involved trap-competition model, both deformation bleaching and the trap-competition are involved for the decrease of TL intensity with the post-irradiation deformation of pure and Cu^{++} doped NaCl crystals.

CONCLUSION

When undoped and Cu^{++} doped NaCl crystals are deformed after irradiation, the TL intensity of the peak I and II decreased linearly with increase value of strain (ε_p). It is found that the intensity for a given TL peak decreases faster as compare to the decrease in the associated F-centre density with the post-irradiation deformation of the crystals. Since deformation bleaching alone is not able to decrease in TL intensity of the crystal but also another factors enhanced number of compatible electron traps are responsible for the decrease in TL intensity with post-irradiation deformation of the crystals.

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