Color centers in Heavy Ion Irradiated Sodium Chloride

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Sodium chloride belongs to class I alkali halide attracts many researchers because of its cubic structure, wide band gap, ionic character and relatively high melting point [1]. The presence of some impurities or lattice imperfections such as color centers (CC) is known to affect the optical, luminescence of the material. Specific CC in AH halide crystals finds applications in color center lasers and information storage media [1,2]. The creation of CC's in NaCl under conventional ionizing radiation viz X-rays, γ-rays, electrons, UV-rays etc have been extensively studied [3]. However, a few attempts were made to understand the defect production by high energy electronic excitations such as swift heavy ions (SHI) [4,5]. When a SHI are passing through a solid target, a huge amount of energy is deposited through inelastic collision with target electrons which in turn induces new and yet incompletely known damage process. In particular, close to ion path, extremely high energies are deposited in a very small volume of some hundreds of eV nm^{-3} with in an extremely short time difficult to reach by any other radiation source. The high electronic excitation density in the core region has strong influence on the resulting defect creation, whereas the damage in larger halo is similar to effects induced by conventional radiations. [6]. In the present study, optical absorption and thermoluminescence of CC's produced in NaCl irradiated with swift heavy ions with various fluences are presented.

EXPERIMENTAL

Single crystals of NaCl used in the present work are grown by Czocralski technique [1]. These crystals are cleaved along (100) plane and obtained crystals of size ($1\times1\times0.1$ cm^3). The thickness of the crystals selected is sufficient to stop the ions in crystal lattice (www.srim.org). The 120 MeV Au^{9+} SHI irradiation is carried out using 15 UD Pelletron at Inter University Accelerator Centre, New Delhi. The electronic energy loss (S_e) and nuclear energy loss (S_n) of 120 MeV Au^{9+} ions in NaCl is found to be 13.51 and 0.185 KeV nm^{-1} respectively. The range of ions is 17.63μm. Optical absorption studies have been performed in the spectral range 200-900 nm using Hitachi U-3300 UV–visible double-beam spectrophotometer. Thermoluminescence (TL) measurements were made using PC based TL analyzer.

RESULTS AND DISCUSSIONS

Optical absorption spectroscopy is a technique which provides a detailed and extensive knowledge about the nature of defects and their concentration under irradiation. Figure 1 shows the optical absorption spectra of pristine and 120 MeV swift heavy ion irradiated NaCl crystals for various fluences.

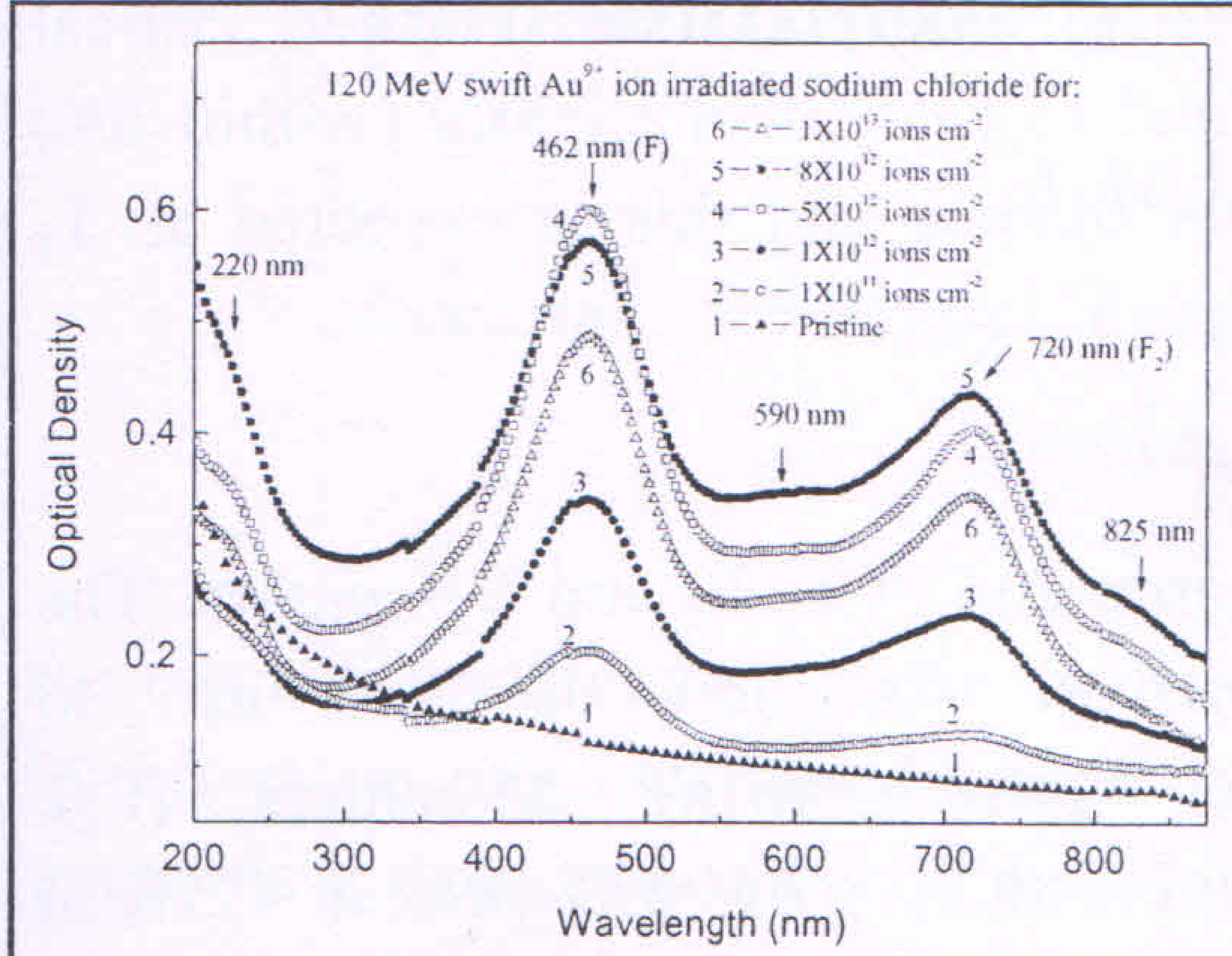
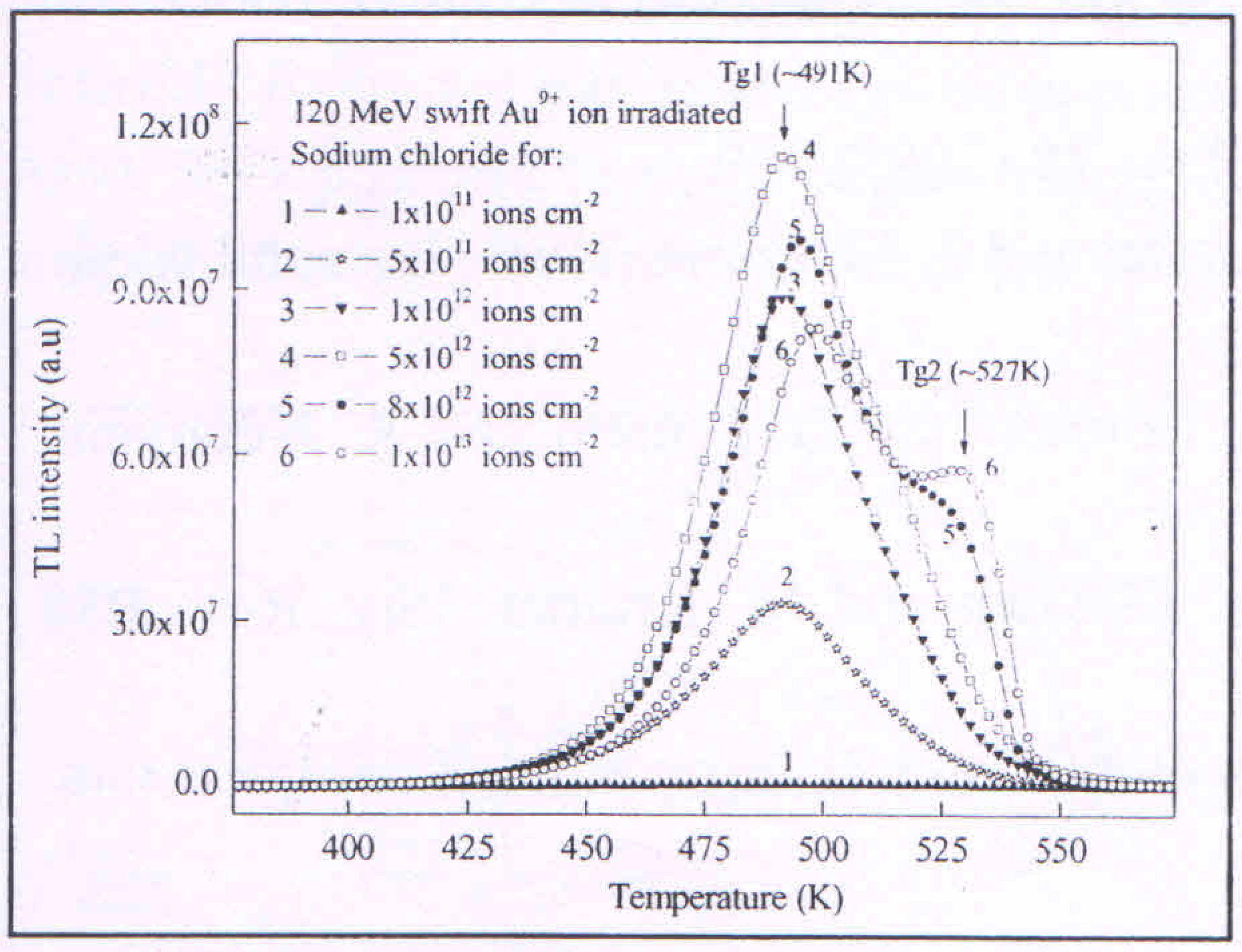


Figure 1. Optical absorption spectrum of 120 MeV swift Au^{9+} ion irradiated NaCl.

Two well resolved absorption bands at 462 and 720nm are observed in all irradiated samples. These bands are assigned to F and F_2-centers respectively [7]. Also, the absorption spectra of irradiated samples exhibit shoulder at 220nm and attributed to V_3-centers. Further, still at higher fluences there are appears two shoulders at 590 and 825nm origination from more complex CC's and they are attributed to F_3 and F_4-centers [7]. All these values are in good agreement with reported values under high density excitation [5]. The absorption at 462nm increases with increase in ion fluence up to 5×10^{12} ions cm^{-2} thereafter it decreases with further increase in ion fluence. This is due to the fact that the concentration of F-centers increases and reaches saturation. Above 5×10^{12} ions cm^{-2} fluence, F-centers reached maximum starts decreasing while M-centers (F_2) starts growing as can be seen from the Figure 1. This trend is observed to be similar in other alkali halides [1]. Further, increase in ion fluence, leads to growth of M-centers, reaches maximum and starts decreasing while F-centers keep on decreasing beyond 5×10^{12} ions cm^{-2} as can be seen from the Figure 1.



Thermoluminescence glow curves of NaCl crystals irradiated with 120 MeV swift Au^{9+} ions in the fluence range 1×10^{11}-1×10^{13} ions cm^{-2} recorded at an heating rate of 1Ks^{-1} is shown in the below figure. A prominent and well resolved TL glow with peak at 491K (T_g1) is observed at all fluences. However, additional shoulder with peak at $\approx$527K (T_g2) is observed in samples irradiated for 8×10^{12} ions cm^{-2} and above. The TL glow peak observed at 491K might be due to the recombination of F-center electron with and V-centers. And, the extra peak appeared at $\approx$527K may be attributed to M-center electrons recombining with V-centers. Further, the TL curves show second order kintecis i.e. the main feature of second order curve is symmetric, with the high temperature half of the curve slightly broader than the low temperature one. This might be due to the fact that in a second-order reaction significant concentrations of released electrons are retrapped before they recombine and resultsin delayed luminescence emission and spreading out of the emission over a wider temperature range [8].

It is observed that TL intensity at (T_g1) increases with ion fluence up to 5×10^{12} ions cm^{-2} and starts decreasing with further increasing in ion fluence. The decrease in TL intensity at T_g1 might be due to formation of nonradiative defect centers and surface amorphization due to high energy deposition on samples at higher fluences. Atomic force microscopy and FTIR spectroscopy may throw some light on the formation of amorphization. Further, critical observation reveals that glow peak temperature is found to be shifted slightly (within 6K) towards higher temperature region with increasing ion fluence and this is expected as T_g depends on various factors [1].

CONCLUSIONS

Swift Au^{9+} ion irradiation on NaCl crystals leads to formation of F, F_2 and V_3-centers. The concentration of F-centers increases with increase in ion fluence up to 5×10^{12} ions cm^{-2} and thereafter it decreases while growing M-centers (F_2). Thermoluminescence studies show a strong and well resolved TL glow with peak at 491K in all irradiated samples. Further, the new shoulder appeared at ~527K is observed at higher fluences. The 491K and 527K glow peaks are attributed to the recombination of F-center and F_2-center electrons with V-centers respectively. The TL intensity at 491K increases with ion fluence up to 5×10^{12} ion cm^{-2} there after it decreases. The decrease in TL intensity is attributed to formation of nonradiative defect centers and surface amorphization of crystals.

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