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Study of conduction current of NaCl and KCl crystals during X-ray radiation

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Abstract The variation of conduction current with time under high constant D C field for NaCl and KCl crystals, has been studied The direction of high constant D C field is kept parallel to the direction of X-ray by holding the crystal between two aluminium electrodes before X-ray beam The change in conduction current due to change in direction of the D C field, has also been studied by changing the polarity of the field The alkali halide crystals thus irradiated by X-ray in the presence of D C field, show Colour centres The concentration of Colour centre due to presence of D C field is found to decrease than the concentration of Colour centres produced by X-ray irradiation only The prominent F and M band peak position are found to be shifted in the longer wave length side due to D C field during X-ray irradiation

On applying D C. field in a direction parallel to X-ray, the conduction current is found to increase rapidly with time It attains a peak value and then decays slowly It reaches to a steady state after about one hour.

When the D C field is reversed *i.e* applied in a direction opposite to X-ray beam, then conduction current decreases slowly for a short time, and reaches to a minimum value Then the conduction curent increases rapidly upto a peak value, after which it decreases slowly and becomes steady in about one hour.

Keywords Colour centres, defects in solid

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1. Introduction

During the last two decades, a remarkable fraction of research in Solid State Physics has been done mainly on 'Defects in Insulating Solids'.

The Development of Colour Centres Laser and the potentiality of its use in optical memory and other devices have added special significance to this field of research. The study of the mechanism of radiation induced colouration in alkali halide and various glasses, is also very vital for radio biology, health physics, detector for nuclear radiation, space exploration and industrial application.

The influence of divalent impurities and of Plastic deformation on radiation induced colouration have excited interest for many years. A substantial enhancement in F-Centre concentration has been observed in A. C. field-treated crystal upon X-ray irradiation by Govinda and Rao [1]. The investigations by Subrahmanyam [2] on NaCl single crystal have shown that a moderately large D. C field during X-ray irradiation has considerable influence on the formation and behaviour of defects. Pohl [3] while measuring the conductivity of coloured specimen of alkali halide, found that under an applied electric field (D.C.), the colour centre cloud migrated towards anode.

In view of the above findings, it was felt that the direction of D. C. field during irradiation, might influence the concentration of colour centre.

2. Method

In the present investigation, thin crystal of NaCl and KCl of the size 2cm × 1cm × 0.1cm were cleaved from a cube of crystal, procured from National Physical Laboratory, New Delhi. The two large faces of the crystal was pressed well between the two thin aluminium foils, which served as electrodes for D. C. field application. The D. C. source was an electronically controlled power supply unit capable to supply voltage from 0 to 3 KV in steps of 10 volts. The crystal was irradiated by X-ray for 1 hour by holding it before X-ray window at a fixed distance. The D C. field was applied simultaneously, keeping the positive electrode, near the window of the tube and the negative electrode which was away from the window, the direction of X-ray was kept same as that of the applied D. C. field.

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In the second case, to observe the effect of direction of D. C. field, a constant D. C. field was applied in a direction opposite to X-rays.

Optical absorption measurements were taken on Spectrophotometer C-4A of Leningrad Optical Instruments, U.S.S.R. for wave length range 220 nm to 1100 nm

3. Results

(1) The optical absorption of the crystal, X-irradiated in the presence of D.C. field

Figure 1 gives the F-band absorption for NaCl under different D.C. fields which is applied in the same direction as that of X-rays Curve I is plotted for Zero field, whereas curve II and curve III respectively are under D. C field 8.62 KV/c.m. and 12 KV/c.m.

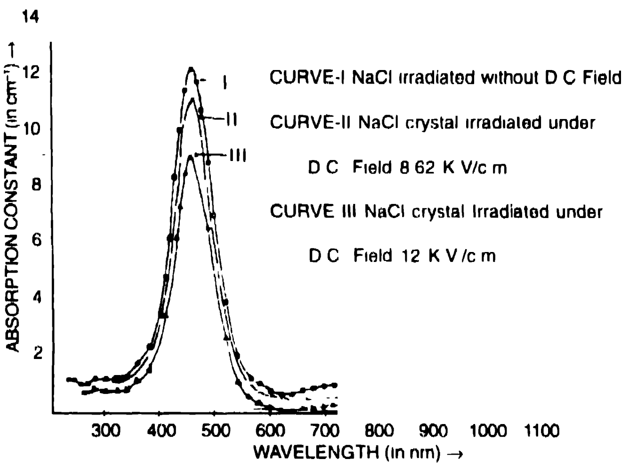


Figure 1.

On comparing the three curves, it is observed that

(i) F-Centre concentration decreases with D. C. field.

(ii) The most prominent bell shaped absorption band is F-band having peak at wavelength 460 nm for curve I, it shifts to 458 nm and 455 nm for curve II and curve III respectively under D.C. field 8.62 KV/c.m. and 12 KV/c.m.

(iii) The absorption constant of the M-band also decreases due to application of D.C. field.

(iv) However due to flat nature of M-band, the peak position is not so prominent Probably due to flat nature of M-band, the shifts of M-band for curve II and curve III are not observed.

Figure 2, presents that absorption constant as a function of wavelength for NaCl crystal when X-irradiated at room temperature under different D. C field of magnitudes 10.416 KV/c.m. and 13.513 KV/c.m. applied in a direction opposite to X-rays. On examining the curves of Figure 2, it becomes evident that :–

(i) The concentration of F-center is enhanced due to application of D. C. field during irradiation which is applied in the opposite direction to X-ray.

(ii) The peak position of F-band for the curve II under D. C. field 10.416 KV/cm shifts to 458 nm under D.C field 13.5113 KV/c.m.

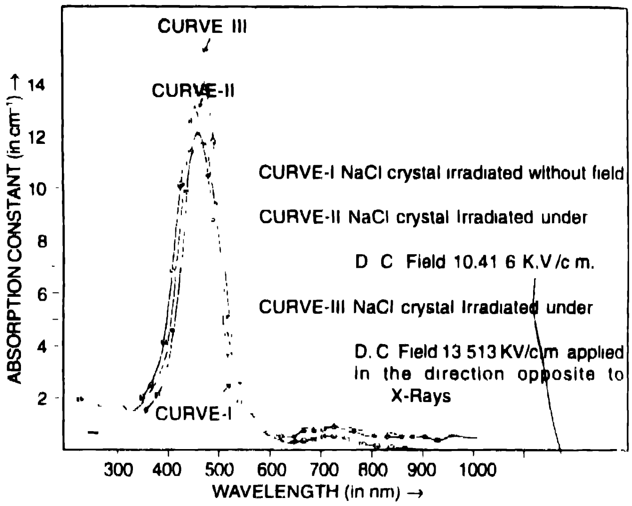


Figure 2.

(2) Variation of conduction current with time during X-ray irradiation

Figure 3 is plotted for conduction current with time for single crystal of NaCl during X-ray irradiation in the presence of D C field of magnitude 19.23 KV/c m. applied in the direction of X-rays beam.

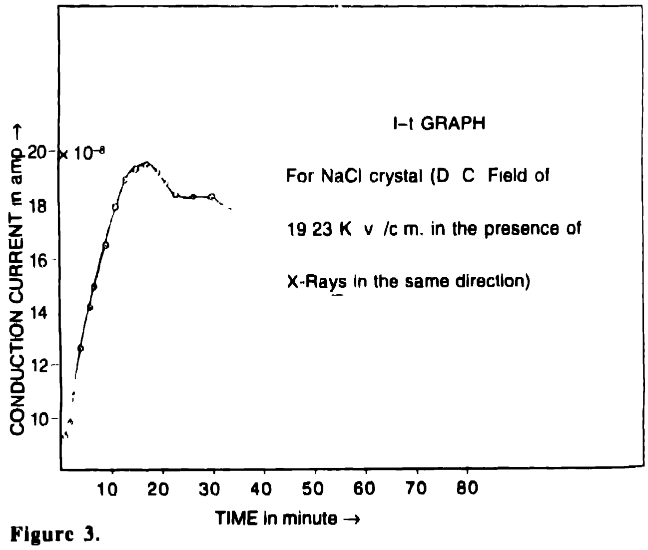
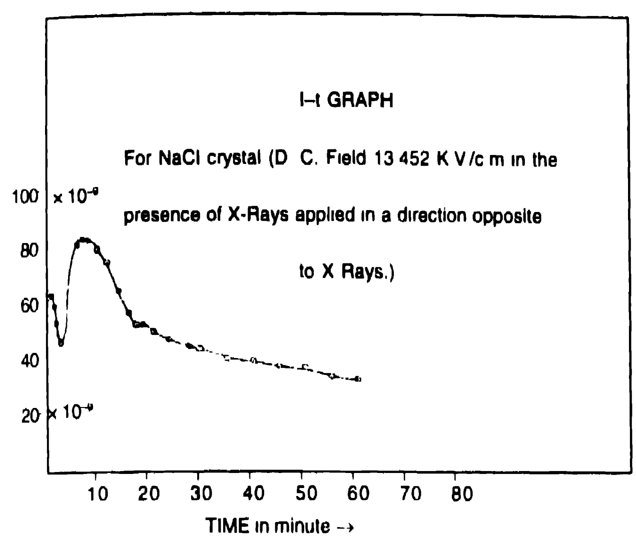


Figure 3.

On examining the curve, the conduction current first increases rapidly with time upto 17 minutes of irradiation, then it starts decreasing. But the decay is very slow and the value is almost constant after 30 minutes.

Figure 4 shows the variation of conduction current under D. field 13.452 KV/c.m. applied in the direction opposite to X-ys



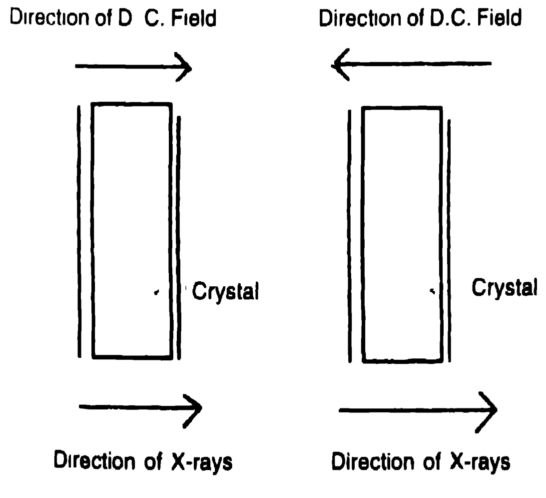
gure 4.

A close observation of the curve indicates that in the ginning, the conduction current decreases for three minutes, en it starts increasing, reaching a peak value after 8 minutes. ie decay of current starts again. Initially, the decay is rapid it it becomes slow after 16 minutes and then the current is most constant after 55 minutes.

Discussion

) Change in colour centre concentration due to D.C. eld.

is well known that FM and R bands are associated with excess ectrons trapped at negative ion vacancies [4]. Free electrons e generated during X-ray irradiation. The probability of apping of free electron inside the crystals at the defects, may be assumed to be influenced by the direction of D.C. field on irradiation the sample in the presence of field opposite to X-rays. The probability of trapping electrons at defects is increased, probably due to repulsion of free electrons from the cathode plate which are kept near the X-ray window.



Under the D.C. field in the same direction as that of X-rays the anode plate remains near the X-ray window and thus decreasing the probability of electron capture at negative ion vancancies, resulting in decrease in colour centre concentration.

(ii) A slight shift of the F-band peak position due to D.C. field during irradiation :

A slight shift in the peak wavelength of F-band, towards higher energy side is observed under the applied D.C. field. The shift is found to be dependent upon the strength of the field but independent of its direction.

According to Ivey Mollow's [5] empirical relation, the energy at the peak of F-band absorption Em is related to inter atomic distance a in the following way.

$$Em\ (\text{in ev}) == (17.6) \times a^{-1.84}.$$

A shift of the absorption band peak position with pressure was also found by Jacob [6] while studying the effect of hydrostatic pressure on F-centre absorption in several alkali halides. They proposed that in alkali halides, the hydrostatic pressure causes a shrinkage in the lattice parameter and in turn, affecting the energy level scheme in which the first excited band F – centre is repeated by a new band, shifted towards the higher energy side.

It seems that the application of D.C. field produces a stress in the crystal resulting in a shrinkage in the lattice parameter. The decrease in inter-atomic distance a causes a shift of the F-band peak position towards the shorter wavelength side *i.e.* higher energy side, which is much similar to the shift produced by hydrostatic pressure.

The optical absorption and conduction current for KCl cystals irradiated by X-rays in the presence of D.C. field show the similar nature. The paper for KCl crystal will be presented else where.

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