CHAPTER VI

EFFECT OF TEMPERATURE ON THE MACH. LUMINESCENCE OF X-IRRADIATED ALKALI HALIDE CRYSTALS

6-1. INTRODUCTION

The effect of temperature in the spectra, intensity and decay time of luminescence has been interesting and it has been widely studied (Surie 1963, Leverenz 1950, Garlick 1949, Goldberg 1966, Di Bartolo 1977). The effect of temperature on the ML has been a subject of particular interest to many workers. Trautz (1909), Van Zolk (1911) and Imhof (1917) have studied ML in certain crystals and found that the ML intensity decreases with the temperature of the crystal. Longchampion (1925) and Stranski et al (1955) have reported that the decrease in the ML intensity of substances with temperature is due to the recombination of ions or atoms. Wick (1937) has investigated the effect of temperature on the ML of fluorite crystals. She concluded that the centres which are affected by a change in temperature are completely, deactivated at higher temperatures. However, the ML due to the electrical discharge in air is not modified by a change in the temperature of the crystals. In the case of sugar crystals, Wick (1940) observed an emission of light at the instant when there was a sudden change in the temperature of the crystals. Metz et al (1957) reported that the ML in X-irradiated KBr, NaCl and LiF crystals increases when their temperature is raised from 10 to 30°C. The decrease in the ML intensity of certain organic
and inorganic crystals has been investigated by Meyer et al (1970), Frohlich and Seifert (1971) and by Das and Chandra (1974). The present chapter describes the effect of temperature on the ML of X-irradiated KBr, KCl, KI, LiF and NaCl crystals.

6.2. EXPERIMENTAL

All the experimental conditions, regarding the size of the crystal, annealing, irradiation are the same as those described in Chapter II. The crystals used in the present investigation were X-irradiated for 40 minutes. For the measurement of the ML at different temperatures, a ceramic cylinder of 5 cm height and 2 cm diameter was placed on the glass platform of the ML measurement device described in Chapter II. A heater coil was wound round the cylinder for heating the crystal, as shown in Fig. 6-1. The heater coil was connected to a variac. By changing the voltage, the crystals could be heated to any desired temperature. The ML measurements were carried out when the device had attained a steady temperature. The temperature of the crystal was measured by a copper-constantan thermocouple. The effect of temperature on a crystal, was studied by applying and releasing a load of 12.5 Kg; using the device described in Chapter II. A piston of 5 cm length attached with a plane mirror at the bottom, was connected to the bottom of the hanger as shown in Fig. 2-3 (Chapter II). Such arrangement was needed to deform the crystal placed inside a cylinder of 4 cm length. To avoid the heating of the photomultiplier tube, a thick
MEASURING DEVICE AT DIFFERENT TEMPERATURES.
1. PMT HOUSING  2. PHOTOMULTIPLIER TUBE  3. RUBBER SHEET
4. LUCITE PLATE  5. HEATING COIL  6. VARIAC
7. CRYSTAL  8. HANGER WITH GLASS BASE  9. WEIGHT
10. THERMOCOUPLE  11. ICE POT  12. SPOT GALVANOMETER
13. ATTACHED TO PRESSING DEVICE.
rubber sheet with a hole at its centre was placed between the glass plate and the photomultiplier housing (Fig. 6-1). Three crystals were studied at each temperature. The error was found to be \( \pm 6\% \).

### 6-3. RESULTS AND DISCUSSION

The ML intensity of X-irradiated KBr, KCl, NaCl, and LiF crystals increases with the temperature of the crystals. The ML intensity of X-irradiated KI crystals decreases with temperature. Figures 6-2 to 6-6 show that the dependence of the ML intensity (during application of the pressure) on the successive number of applications of the pressure follows the relation

\[
I_n^p = I_1^p \exp\left( - \beta (n_p - 1) \right) \quad \text{.. (6.1)}
\]

Figures 6-7 to 6-11 show that the dependence of the ML intensity (during the release of pressure), on the successive number of releases of the pressure follows the relation

\[
I_n^r = I_1^r \exp\left( - \beta_r (n_r - 1) \right) \quad \text{.. (6.2)}
\]

\( \beta \) and \( \beta_r \) increases with the temperature. However, for a given temperature, the value of \( \beta_r \) is always less than the value of \( \beta \).

The ratio of the ML intensity during the release to the ML intensity during the corresponding number of application of the pressure, decreases with the temperature of the crystals.

Figure 6-12 reveals that the total ML intensity, that the sum of the areas below the \( I_n^p \) versus \( n_p \) and \( I_n^r \)
versus \( n \) curves, of X-irradiated KBr, KCl, NaCl and LiF crystals increases with the temperature. However, the total intensity of the ML of X-irradiated KI crystals decreases with the temperature.

For the study of temperature effects on the ML of the crystals, the crystals were placed on the glass plate (Fig. 6-1) which was in a steady state. The time of annealing at this temperature, does not have any considerable change on the ML intensity of X-irradiated KBr, KCl, NaCl, and LiF crystals. The ML intensity of X-irradiated KI crystals decreases with the time of annealing as shown in Figures 6-13 and 6-14.

The ML intensity is directly related to the density of the colour centres (Netz et al 1957, Butler 1966) and the density of the colour centres is directly related to the area below the thermoluminescence glow curves of the crystals (Ausin and Álvarez-Hivas 1972, Jain and Mehendru 1965). Hence, the ML intensity can be normalized for the decrease in the density of the colour centres with the temperature of the crystals with the help of thermoluminescence glow curves. For normalizing the ML intensity, the total ML intensity \( I_T \) at a given temperature \( T \) was multiplied by \( A_T / (A_T - \int_T^\infty I_{TL} \, dT) \), where \( I_{TL} \) is the TL intensity, \( A_T \) is the total area below the glow curve, and \( T_0 \) is the room temperature. The value of \( \int_T^{\infty} I_{TL} \, dT \) was estimated from the area below the glow curve from room temperature to the temperature \( T \), because the TL measurements (in Chapter V) were started from the room temperature. Figure 6-15
illustrates that the plot of \( \log I_T / A_T \left( A_T - \int_{T_o}^{T} I_T dT \right) \) versus \( 1/T \) is a straight line with a negative slope, for X-irradiated KBr, KCl, LiF, and NaCl crystals. This result suggests the relation

\[
\frac{I_T / A_T}{A_T - \int_{T_o}^{T} I_T dT} = A_o \exp \left( - \frac{E_o}{kT} \right)
\]

where \( A_o \) is constant, \( k \) is the Boltzmann constant and \( E_o \) is the activation energy. The values of \( E_o \) estimated from Figure 6-15 are found to be 0.24, 0.75, 0.27, and 0.32 eV for X-irradiated KBr, KCl, LiF, and NaCl crystals respectively.

The annealing time strongly decreases the density of colour centres in \( KI \) crystals. The decrease in the ML intensity of X-irradiated \( KI \) crystals with the temperature may chiefly be due to the decrease in the density of colour centres with the annealing time. Since the annealing time decreases the density of colour centres in X-irradiated \( KI \) crystals, it is not possible from the ML measurements to determine the activation energy for the increase in the number of dislocations with the temperature.

It is seen from Figure 6-2 to 6-6 that the difference between the extrapolated and the experimental values of \( I_1^p \) decreases with increasing temperature of the crystals. This fact suggests that the higher experimental values of \( I_1^p \) may be due to the presence of shallow traps.

The physical significance of \( k_o \), increase in the value of \( \beta \) and \( \beta_o \), with the temperature, and the decrease in the ratio of \( I_{n1}/I_{n1}^p \) with temperature will be discussed in Chapter VII.
Fig. 8.2-Plot of log of the ML intensity during pressing versus \((n_p^{-1})\) in KBp crystals at different temperatures.
FIG. 6:3- PLOT OF LOG OF THE ML INTENSITY DURING PRESSING VERSUS $\log p$!
IN KCl CRYSTALS AT DIFFERENT TEMPERATURES.
FIG. 8.4- PLOT OF LOG OF THE ML INTENSITY DURING PRESSING VERSUS ($\eta_p - 1$)
IN KI CRYSTALS AT DIFFERENT TEMPERATURES.
FIG 6.5: PLOT OF LOG OF THE ML INTENSITY DURING PRESSING VERSUS \((n_p-1)\)
IN LiF CRYSTALS AT DIFFERENT TEMPERATURES.
Fig. 6.6 - Plot of log of the ML intensity during pressing versus $\log(1-n_p)$ in NaCl crystal at different temperatures.
FIG. 6.7 - PLOT OF LOG OF THE ML INTENSITY DURING RELEASE VERSUS ($n_f^{-1}$) IN KBr CRYSTAL AT DIFFERENT TEMPERATURES.
PLOT OF LOG. OF THE ML INTENSITY DURING RELEASE VERSUS ($n_r-1$) IN KCl CRYSTALS AT DIFFERENT TEMPERATURES.
Figure 9: Plot of log of the ML intensity during release versus $(n_r-1)$ in KI crystals at different temperatures.
Fig. 6.10 - Plot of log of the ML intensity during release versus \((n_r-1)\) in LiF crystals at different temperatures.
Fig. 8-11: Plot of log of the ML intensity during release versus \((n_T-1)\) in NaCl crystals at different temperatures.
Fig. 8.12—Effect of temperature on the total ML intensity, $I_T$, of $X$-irradiated KBr, KCl, KI, LiF, and NaCl crystals.
FIG. 8.13 - PLOT OF LOG OF THE ML INTENSITY VERSUS (n_p^{-1}) FOR DIFFERENT TIMES OF ANNEALING AT 40°C FOR X-IRRADIATED KI CRYSTALS.
Fig. 6.4 - Plot of log of the ML intensity versus ($n_f^{-1}$), for different times of annealing at 40°C, for X-irradiated KI crystals.
Figure 8: Plot of $I_T \times A_T / (A_T - \int_0^T I_{TL} dT)$ versus $1/T$. 
REFERENCES


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