CHAPTER FIVE

GENERAL DISCUSSION AND CONCLUSIONS

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This chapter is devoted to the general discussions of the results obtained in the present investigation. Although some interpretations and inferences drawn from specific studies are described at the end of the preceeding chapters, they are summarised and further discussed.

5-1 EL Brightness-Voltage Relation:

It has been found that the plots between log B and log V exhibit fair linearity over a wide range of voltages implying a power law relation,

[illegible]

$$B = a \left(V - V_0 \right)^n \qquad ---- \qquad (5.1)$$

with $V_0=0$ and a and n are constants, to hold good between B and V. Besides the power law, a relation

$$B = a \exp. \left(-b/ \sqrt{V} \right) \qquad ---- \qquad (5.2)$$

with a and b as constants; is also found suitable over a limited range of voltages. Such a simultaneous validity of both the equations was also observed by other workers (1,2,3).

5-2 EL Brightness-Frequency Relation:

In most of the studies on frequency dependance of electroluminescence (3,4,5,6,7), it is observed that the EL brightness increases more or less linearly with frequency. However, a few workers have reported the decrease of EL brightness with increase in frequency (8,9). The depend~~a~~ence of EL brightness in the present study is very similar to that reported by Piero et al (8). The decrease of EL brightness with increase in frequency cannot be accounted for by means of simple physical models (8). It involves much theoretical complications (9) and rather troublesome questions (8).

The frequency independent nature of EL brightness, observed at higher frequencies, can be explained on the basis of the theories proposed by Thornton (4) and Curie (6,7). At moderately high frequencies the equation given by Thornton (9) viz.,

$$B = N_o f \left[\; 1\text{-exp.} \; ({}^{-A}/f) \; \right] \qquad - - - - \qquad (5.3)$$

approximates to,

$$B = N_o A \qquad - - - - \qquad (5.4)$$

As N_o is the number of excited centres for each half cycle, which is a function of applied voltage, the equation predicts the effect of voltage on frequency depend~~a~~ence of brightness. Moreover, the equation given by Curie (6,7), viz,

$$B = B_o \frac{n_o^2}{\left(1 + \frac{n_o^2}{2f} \right)} \qquad - - - - \qquad (5.5)$$

at high frequencies takes the form,

$$B = B_o n_o^2 \alpha \qquad - - - - \qquad (5.6)$$

The expression is independent of frequency and points to the frequency independent EL brightness.

5-3 Electrical Characteristics of Phosphors:

The variation of device current (I) with applied a.c. voltage (V) exhibits two distinct regions, and relations $I \propto \exp\,(a/v)$ and $I \propto \exp\,(aV)$ are found to hold good in these regions. This implies that the exhaustion barrier of Mott-Schottky type exists in the phosphor (11) and the width of barrier increases as the square root of applied voltage. This is supported by the power dependence of device current on brightness (Fig.3.14).

5-4 Effect of Addition of Activator on Electroluminescence Behaviour:

For various samples containing different concentrations of the activator (Zn), it has been found that the nature of voltage and frequency dependence of brightness and electrical characteristics is similar. This implies that the activator does not significantly affect the EL characteristics of these phosphors.

5-5 Mechanism of Electroluminescence:

Phosphors in the present investigation required comparatively high fields for EL emission (Threshold voltage being greater than 350 volts). This behaviour, along with the existence of power law relationship between brightness and voltage, suggests that the probable mechanism of excitation in these phosphors is likely to be the direct field ionisation of either the valence band electrons or impurity centres, where transfer of electrons in the conduction band takes place by quantum mechanical tunneling process (11). Besides the power law, a relation $B = a \exp. (-b/ \sqrt{V})$ is also found suitable over a limited range of voltage, indicating thereby the luminescence emission also results from a potential barrier of Mott-Schottky type, where field is proporsional to $\sqrt{V}$; and mechanism of excitation is acceleration collision type (12). The studies of electrical characteristics also go in favour of existence of potential barrier of Mott-Schottky type. Thus, it may be concluded that the probable mechanism of EL in these phosphors is likely to be the direct field ionisation of either valence band electrons or impurity centres, where transfer of electrons into the conduction band takes place by quantum mechanical tunneling process through the Mott-Schottky type barrier existing at the grain boundaries. These electrons at the latter stage recombine radiatively with impurity centres or holes created in the valence band giving EL emission.

5-6 Kinetics of Luminescence:

The kinetics of luminescence is inferred from electroluminescence measurements. The inference goes in favour of intermediate kinetics. The existence of power law relation between brightness and voltage points the possibility of bimolecular process (13). However, as exponential relation is also found suitable over a certain range, the process cannot be said to be purely bimolecular but an intermediate. Such an intermediate mode of kinetics is shown to be feasible by Chen (14), Muntoni et al. (15) and Kathuria and Sunta (16).

5-7 EL-TL Curves:

EL-TL curves are found to differ from normal glow curves. The normal glow curve exhibits two maximum while EL-TL curve a maximum followed by a minimum. The results are in accordance with Bhushan and Saleem (17) and Johnson et al. (18).

5-8 Effect of Variation of Voltages and Prequency on EL-TL Behaviour:

An increase in voltage, at constant frequency, is found to shift the positions of maximum and minimum towards the low temperature side while change in frequency has the reverse effect except that the position of minimum shifts towards the lower temperature side. The effect could be accounted for on the basis of Thornton's consideration (4) that, in presence of field the trap depth of the effective level increases with frequency and decreases with the field strength.

5-9 Effect of Electric Field on The Release of Electrons From Traps And Their Recombination with Luminescence Centres:

It has been found that an application of electric field modifies the TL intensity significantly. This implies that the release rate of electrons from traps and their recombination with luminescence centres is influenced by the presence of electric field. The effect can be understood in two ways : According to first view, the process of release of electrons from traps in presence of field is similar to that in normal TL. These electrons then get transferred to exhaustion regions from where they do not merely recombine with luminescence centres, as that in TL process, but are accelerated to optical energies so as to ionise more luminescence centres and hence to modify the TL intensity.

The second view takes into account the difference between the probabilities of escape of electrons from a trap situated in high or low field region and that in absence of field. Moreover, here, it is assumed that the probabilities of escape of electrons trapped in high and low field regions also differ from each other. Thus, as per this view, an application of electric field and its variation will apparently increase or decrease trap depth of effective level. This is as good as saying that the release of electrons from the traps and their transfer to the excitation region is controlled by the electric field.

5-10 Mechanism of EL-TL:

Trapping states and exhausion barrier are found to exist in the present phosphor system. Moreover, the observed EL-TL behaviour could be explained on the basis that, the filling and ~~the~~ emptying of traps has an effect on the field strength across and within the potential barrier and hence on the emitted intensity. This suggests that the probable mechanism of EL-TL process involves the transfer of electrons, released from the traps, to the exhaustion barrier where they are accelerated to optical energies to ionise luminescence centres by impact ionisation. The intensity of radiation is being controlled by the field across and within the exhaustion barrier; and in turn by filling and emptying of traps.

5-11 An EL-TL Phenomenon - A Correlation Between Thermoluminescence and Electroluminescence:

A comparision of normal glow curve with that obtained under the application of electric field indicates that the presence of trapping states in a phosphor affects the EL intensity emitted at different temperatures. Therefore, in order to investigate the performance of an EL device involving trapping levels, a correlation between TL and EL is necessary. The phenomenon of EL-TL can be regarded as a necessary tool for the purpose.

5-12 Conclusions:

The principal findings of the present investigation may be summarised as follows:

1. EL brightness (B) and applied voltage (V) follow the relation

$$B = a\,(V - V_o)^n$$

with $V_0 = 0$ and a and n as constants, over a wide range of voltages; while a relation

$$B = a \exp. \left(-b/\sqrt{V} \right)$$

with a and b as constants, over a limited range.

2. EL brightness is found to decrease with increase in frequency.
3. Mott-Schottky type exhaustion barriers are found to contribute to the emission process.
4. Probable mechanism of EL process in these phosphors is likely to be the direct field ionisation of either valance band electrons or impurity centres, where transfer of electrons into the conduction band takes place by a quantum mechanical tunneling process through the Mott-Schottky type barrier existing at the grain boundaries. These electrons, at a latter stage recombine radiatively with impurity centres or holes created in the valence band giving rise to EL emission.
5. Application of an electric field during thermoluminescence modified significantly the emitted intensity.
6. Filling and emptying of electron traps, in presence of electric field, changes the field strength across and within the potential barrier, which in turn, controls the emitted intensity during the EL-TL process.

7. Probable mechanism of EL-TL process is exhaustion mechanism and involves the transfer of electrons, released from traps, to the exhaustion barrier where they are accelerated to optical energies to ionise luminescence centres by impact ionisation, which in turn emit the radiation.

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