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# A.C. THIN FILM ELECTROLUMINESCENCE

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## ABSTRACT

This article is to summarise basic mechanisms and operating characteristics of A.C. thin electroluminescence (ACFEL) and review its viability as large panel display device.

## INTRODUCTION

Electroluminescence is the emission of light as a result of an applied electric field across phosphorescent materials. Electroluminescence in silicon carbide crystal was first reported by Lossev<sup>1</sup> in 1923. In 1936 Destriau<sup>2</sup> succeeded in getting electroluminescence in zinc sulfide in which an A.C. field was applied to a suspension of phosphor particles in a dielectric between two parallel electrodes. Several workers namely Curie<sup>3</sup>, Piper and Williams<sup>4</sup> explained that electroluminescence of ZnS is due to acceleration of charge carriers to optical energies in high field. Since then intense research effort was carried out in 1950's but ended in mid-sixties due to poor life, brightness and efficiency of both A.C. and D.C. electroluminescent devices. The interest was aroused again in mid-seventies by significant progress made in Japan with ACFEL and in Great Britain with D.C powder electroluminescence i.e. DCPEL<sup>5</sup>.

## STRUCTURE OF ACFEL<sup>6</sup>

Although there are various combinations of materials for active materials and insulator, here the discussion is focussed on the ZnS : Mn being used as active material. Insulator material could be one of the following materials :  $Y_2O_3$ ,  $Al_2O_3$ ,  $BaTiO_3$ ,  $Si_3N_4$ ,  $SiO_2$  and plastic materials. The basic structure consists of phosphorescent material ZnS : Mn which is sandwiched between two insulators. An a.c. source is applied to aluminium contact on the top and transparent conductor at the bottom as shown in figure 1. The whole structure is attached to glass substrate.

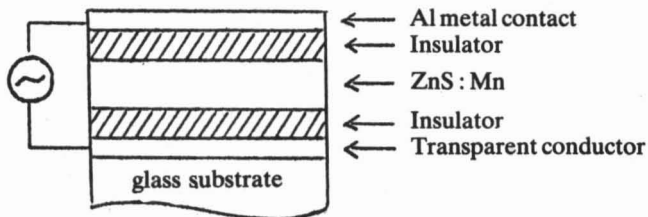
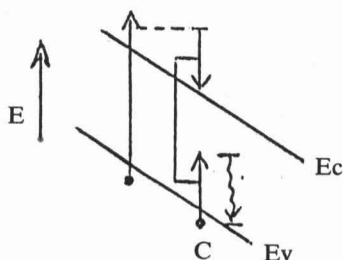


Fig. 1. Structure of an ACFEL device

## BASIC MECHANISM OF ACFEL

Bound electrons in valence band are excited to conduction band upon the application of high field, and accelerated to sufficient kinetic energies so that collision excitation of luminescent centres occurs. This can be shown in figure 2.



**Fig. 2 Mechanism of ACFEL : ionization of bound electrons, acceleration in field and then collision excitation at C<sup>9</sup>**

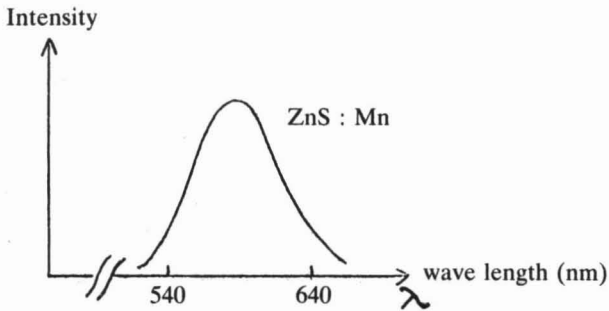
The luminescent centres which can be excited must have adequate cross-section for collision by electrons and possess good stability in high field when excited so that luminescent emission can take place before ionization. Although this partially explains the general behaviour, but the question of energy distribution of electrons still remains a mystery.

There are three models available for the energy distribution of carriers in high field, namely ballistic, streaming and Maxwellian. Among the three models, streaming type of distribution is favoured. The streaming electrons experience no inter-electron scattering but encounter some phonon-scattering. The cross-section for collision excitation is very much related to the ground state of dopant with respect to the band edge. It was found that  $Mn^{2+}$  lies approximately 3 eV below the valence band edge. For rare-earth dopant, the energy level lies even deeper, which signifies a lower collision cross-section. Since efficiency increases with cross-section, this explains why  $Mn^{2+}$  usually has a higher electroluminescent efficiency than other rare-earth dopants.

## OPERATING CHARACTERISTICS

### a) Emission Spectra

The emission from  $Mn^{2+}$  dopant gives the characteristic yellow colour. It covers a wavelength range of about 540 - 640nm. Although other dopants are used to give different colours but their efficiencies are low as compared to  $Mn^{2+}$ .



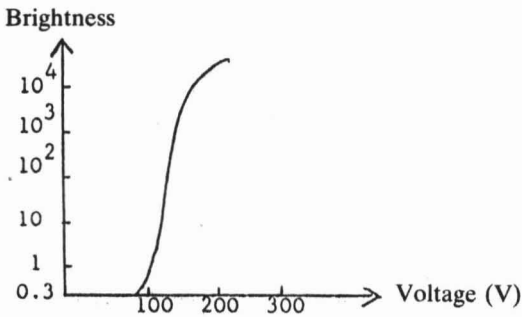
**Fig. 3 Emission Spectrum from ZnS : Mn**

**b) Voltage dependence of brightness.**

For ACFEL cells, the brightness - voltage dependence has been found to be in the following form.

$$L = L_0 \exp\left(-\frac{V_0}{V}\right)$$

Where  $L$  &  $V$  are brightness and r.m.s value of voltage respectively, and  $L_0$ ,  $V_0$  are parameters that depend on layer thickness, dielectric constant of insulator. A typical graph of brightness VS. voltage for a thin film electroluminescent device is shown as follows.



**Fig. 4 Brightness - voltage curve for ZnS : Mn**

### c) Frequency Dependence of Brightness

Brightness is approximately proportional to the exciting frequency at low frequency, saturates at a sufficiently high frequency and tends to decrease at higher frequency. Such characteristics is observed by R.E. Halsted and L.R. Koller<sup>7</sup>. It has been studied that light emits only one pulse per voltage cycle<sup>4</sup>. It is this relation that determines the frequency dependence of brightness.

### d) Efficiency

In general efficiencies of electroluminescent devices depend very much on the exciting voltage. It normally increases with voltage and when it reaches its maximum value, it then goes down with the voltage again as shown in fig. 5.

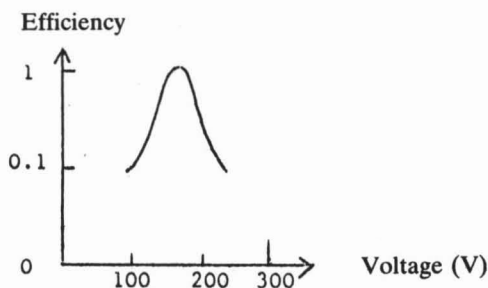


Fig. 5. Variation of efficiency with voltage for ZnS : Mn

## VIABILITY OF ACFEL DEVICES

The non-linearity of the brightness-voltage curve at peak luminescence obtained for ZnS : Mn is very suitable for matrix addressed devices. Although rare earth fluorides in ZnS offer a range of colours from red to blue, they are not as efficient as ZnS : Mn.

On the operating life of ACFEL, it shows a so called burn - in period in the range of few hours to a few hundred hours depending on the operating condition. During this period the brightness - voltage curve is shifted to a higher voltage by about 15 - 20% of its initial value, but no degradation has been observed for more than 20,000 hours after burn - in period<sup>5</sup>. If the ACFEL device is encapsulated by epoxy, the luminescence does not show degradation for at least 5000 hours<sup>8</sup>.

There are many advantages besides those mentioned in the above, these can be summarised in the following table<sup>5</sup>. Listed in the table include A.C. Powder electroluminescence (ACPEL), D.C. powder electroluminescence (DCPEL) and D.C. film electroluminescence (DCFEL) for comparison.

<b>TYPE</b>	<b>ADVANTAGES</b>	<b>DISADVANTAGES</b>
ACPEL	Easy to produce Cheap Efficient Multicolour	Non-multiplexable Low contrast Insufficient maintenance a.c. 5 KHz 100V
DCPEL	Cheap Multiplexable d.c. operation Prototype available	Low contrast High current Low efficiency Not multicoloured
ACFEL	High contrast High brightness Fully transparent Multiplexable  High resolution Very good maintenance Efficient	a.c. 5 KHz, 150V Electical tolerances small High capacitive current Burn-in necessary  Not multicoloured
DCFEL	High contrast Low voltage d.c operation Multiplexable	Less developed technique So far inefficient Not multicoloured

By weighing the advantages over disadvantages and by making comparison with the performance of other electroluminescent devices, it is obvious that ACFEL device is far superior to other types of electroluminescent devices, particularly in terms of good contrast, excellent brightness and long operating life.

## CONCLUSION

Although there are still problems associated with the understanding of the operation of ACFEL devices, especially in the area of carrier dynamics in the insulator as well as active layer. It is hoped that deeper understanding of this mechanism in future will help in increasing the luminescent efficiency. Further more the technology of thin film fabrication for large panel still makes the cost unacceptable at the moment. It is also hoped that the technology will be improved once the actual carrier dynamics is well understood. At this juncture one can conclude that the ACFEL device has the greatest potential as large area display device since its discovery in 1936.

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