PHOSPHOR EFFICIENCY AND DEPOSITION TEMPERATURE IN ALTERNATING CURRENT THIN FILM ELECTROLUMINESCENCE (ACTFEL) DISPLAY DEVICES

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Dedicated to my mother

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by

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CHAPTER 1

INTRODUCTION

1.1 Statement of purpose

The primary purpose of this thesis is to study the effects of high temperature deposition of phosphor layer on the phosphor efficiency and crystal structure in alternating current thin film electroluminescent (ACTFEL) display devices. The material used for the phosphor is Zinc Sulphide doped with Mangnaese and the deposition process is electron beam evaporation. This is a pioneering work to study the effect of changing the substrate temperature on phosphor efficiency aimed at increasing the light output from the phosphor. Materials used in the construction and basic operating principles are described in the first few sections of this thesis. This is followed by sections on the fabrication procedure and characterization techniques. This lays adequate foundation to appreciate the more involved discussion on high temperature deposition of phosphor on the phosphor efficiency and crystal structure described in next section. Finally, results of a fundamental study on the contamination control in the fabrication of ACTFEL devices is described.

1.2 Introduction to ACTFEL Display

There is a large and continued demand for various types of display devices. The traditional

and still the most predominant form of display is the Cathode Ray tube (CRT) because of its low cost, colored display, and high resolution. However, in the present age of the electronic industry where the size of every electronic device is shrinking there is a continuously increasing demand for a thin, light weight, and rugged form of display. Among the many possible alternatives the alternating current thin film electroluminescent (ACTFEL) display is potential display device for the future.

The basic principle involved in the operation of a ACTFEL device is a phenomenon called electroluminescence (EL) which can be defined as a non-thermal generation of light resulting from the application of an electric field to a substance. There are four types of displays based on the principal of electroluminescence. These are ac thin film EL (ACTFEL), ac powder EL, dc thin film EL, and dc powder EL. Among these, two types are commercially available: ACTFEL devices are used as flat screens for laptop personal computers and word processors, and ac powder EL devices are used as backlights for liquid crystal displays.

ACTFEL devices have a good chance for wide commercialization. They are all-solid, emissive display devices with a number of superior characteristics. These include, fast response, wide viewing angles, high resolution, wide operating temperatures, light weight, and good display qualities. These features ensure suitability to high information-content flat panel screens of personal computers and workstations. However, these are presently available as a single color display only. A number of multicolor models have been developed and tested, but a considerable amount of research work is needed to have a competitive, and efficient commercial multicolor ACTFEL

display.

1.3 ACTFEL Display, a Historical Perspective

The phenomenon of electroluminescence was known as early as in 1924, when Lossav[1] reported the excitation of light by an applied voltage in Silicon Carbide crystals. However, the first high-field electroluminescence was discovered by Destriau[2] in 1936. He observed light emission from a ZnS phosphor powder dispersed in an insulator and sandwiched between two electrodes when a high ac voltage is applied. From 1936 to 1960, most of the research work was focused on ac powder EL devices. In late 1950's and 1960 focus shifted to thin film EL structures when Vlasenko and Popkov [3] observed a steeper rise in luminance with respect to voltage, higher luminance, and superior contrast in yellow emitting ZnS:Mn thin film EL devices as compared to powder EL devices.

A significant step forward was taken in 1967 by Russ and Kennedy [4] when they introduced a double-insulating-layer type ACTFEL structure, which is still the basic structure of thin film display. Efforts continued to improve the reliability, and performance of these devices, and in 1974 SID (Society of Industrial Display) International Symposium Inoguchi *et al.* [5] announced that the luminance of 1000 fL at 5-kHz driving voltage could be maintained for more than 10,000 Hrs in ZnS:Mn ACTFEL devices. Also, at the same time Mito *et al.* [6] showed that these devices could be used for TV imaging system.

Finally in the mid 80's a half-page 9-inch-diagonal ZnS:Mn yellow emitting ACTFEL device was introduced in the market indicating the maturity of ACTFEL technology for commercial application. In the last few years ACTFEL displays have found rapidly growing applications in the areas of industrial instrumentation, and computers. The main challenge today is to produce efficient multi-color ACTFEL displays for commercial applications. To achieve this, focused research is going on all over the world including the Electronic Devices Laboratory in University of Texas at El Paso.

1.4 ACTFEL display, Present and Future

There has been a rapid improvement in ACTFEL display technology since the introduction of first commercial ACTFEL display in mid 80's and it is projected to continue (Fig.1.1 [7]). ZnS:Mn ACTFEL displays have gained large acceptance in demanding display applications where excellent viewing characteristics are necessary, and are now available in different sizes up to full sizes for workstations. The most common displays are 640x400 and 640x480 pixel half page displays for personal computers and word processors. ACTFEL applications are also common in industrial instrumentation where good contrast must be maintained in a very high ambient illumination.

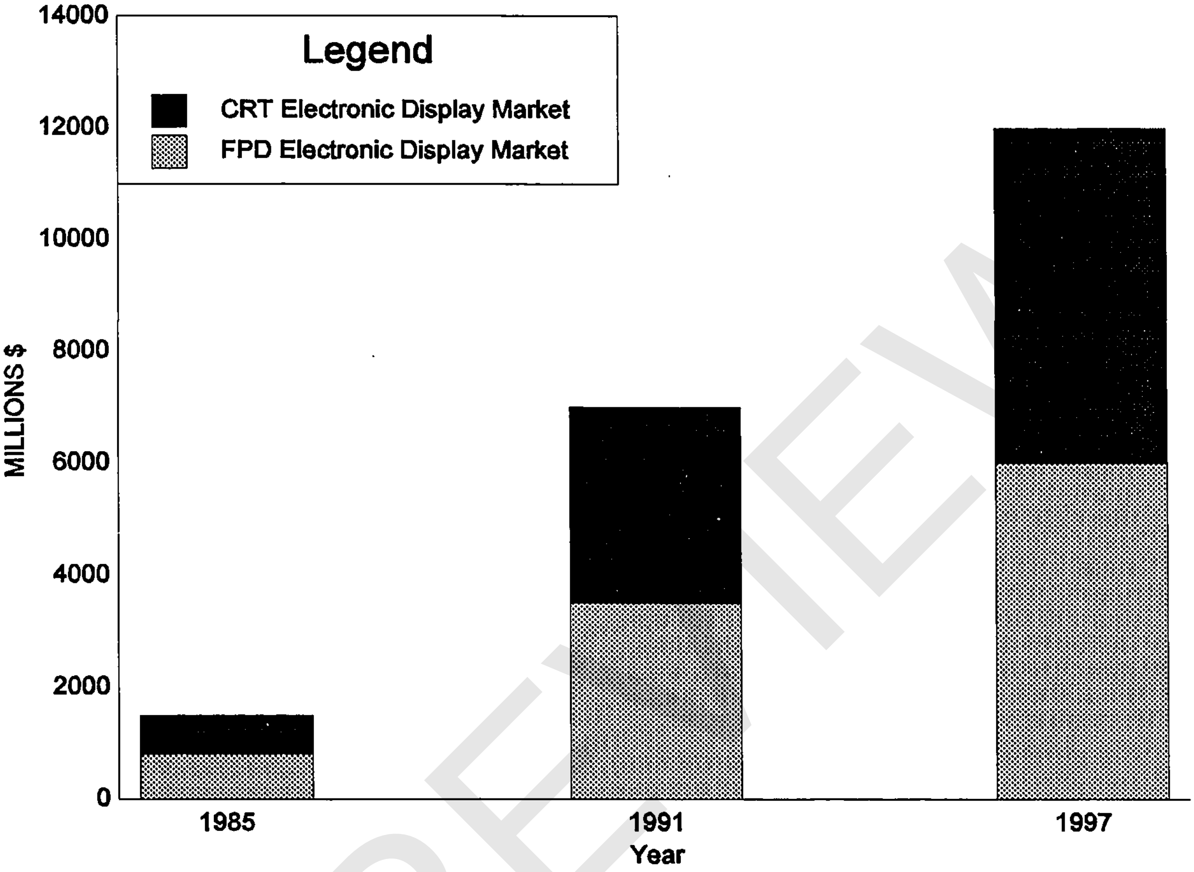

Fig.1.1: FPD Display Market

At present there are a number of competitive technologies striving to replace the old, but still most reliable, CRT's. These include Active and Passive liquid crystal displays (LCD's), plasma displays, field emission displays. Among these, the Active matrix LCD's are considered to be the top contender for flat panel displays. However, with its unique features including high legibility, high contrast, wide viewing angle(>160°), fast response time (several microseconds), and capability

for very high resolution ACTFEL displays have the capability to become the most widely used displays of future.

The biggest challenge today for ACTFEL technology is to produce a multicolor display. Manufacturing of practical multicolor displays was long delayed due to insufficient luminance of the primary colors, red, blue, and green. Recently however, progress in the development of the multicolor display structure and color phosphors made it possible to fabricate the first multicolor ACTFEL display [8]. The color blue is still inadequate for practical display applications, but recent laboratory results are now close to what is required. Using a cerium activated calcium thiogallate ($CaGa_2S_4$:Ce) phosphor, Barrow *et al.* [9] reported a deep blue luminance of 13 cd/m^2 measured at 60-Hz pulse. Work continues to find a more efficient blue phosphor all over the world including the Electronic Devices Laboratory at University of Texas At El Paso. Here, experiements are being carried out using Germanium as an activator in the phosphor layer (ZnS).

It is believed that the advancement in the flat panel displays and wireless communications are going to drive the next revolution in the electronic industry, the personal communication revolution, following the revolution in personal computing in 80's. The ACTFEL displays are considered to be one of the main benefactor of this revolution. This portends a tremendous growth in the ACTFEL technology in near future.