ANALYSIS OF BULK SPACE CHARGE EFFECTS IN
A SrS:Ce ACTFEL DISPLAY DEVICE

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ABSTRACT

In this thesis an analysis was done on the effects of bulk traps, their concentrations, activator concentration and tunneling probability (SIGMA2) on the performance of a SrS:Ce a.c. thin film electroluminescent device. This is an extension of a theory developed by Dr. Vijay P. Singh. A simulation program, scripted in C, is developed to calculate the electric field, the charge transferred in the phosphor region, and the luminescence produced by electron impact excitation. The luminance as a function of time calculated from the model was analyzed, various parameters, and their effects, are studied.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Introduction of Electroluminescence

The most efficient way for a machine to communicate with a human operator is by way of an information display device. There is a large demand for various types of display devices. At the present time, the cathode ray tube (CRT) occupies the dominant position. Although CRT's provide satisfactory performance in terms of the display contrast, brightness and long life, they have several undesirable features. CRT's are too bulky; they consume too much power and require very high voltages for operation. In addition, the manufacturing costs are high, they emit undesirable electromagnetic radiation, and it is difficult to make a large display screen out of them. To circumvent these problems, alternative flat panel display devices, which are capable of displaying a large volume of information, have been proposed. The flat panel electroluminescent display devices, which are solid state,

rugged, lightweight, portable and have low power consumption, are of great interest. Also, electroluminescent display devices are capable of producing bright light while operating under direct sun light.

Electroluminescence (EL) is a phenomenon of light emission obtained by applying a strong electric field across the bulk of a phosphor material. As early as 1924, Lossev [5] reported light emission by applying a voltage to silicon carbide crystals. In 1936 Destrian [6] reported the electroluminescence of ZnS by using an alternating current. W. Piper first proposed the structure for an EL display matrix array in 1953.

In 1978, Inoguchi et al. [7] produced stable, high-brightness EL panels using the a.c. thin film (ACTFEL) technology and demonstrated a 240 by 320-line ACTFEL monochromatic TV at a consumer electronics show. Interest in EL display was revived and a major pursuit for multi-color TV using, an EL display device was launched.

1.2 The ACTFEL Display Devices

The first attempt to produce multi-color electroluminescence devices employed ZnS as host phosphor. It was doped with various rare-earth activators to obtain the desired colors. Europium and Samarium were used to obtain red luminescence. Terbium and Thulium were used to obtain green and blue.

Yellow emitting ZnS: Mn thin film EL display panels have been developed and are now commercially available. $ZnS:TbF_3$ devices also yield sufficient green luminescence levels [8]. But the red and blue luminescence levels are currently still too low.

Alkaline-earth sulfides offer an alternative as luminescent host materials [9]. Since there is close similarity between the ionic radii of rare-earth ions and the ionic radii of the cations of SrS and CaS, the rare-earth activators can be expected to be more fully incorporated in SrS and CaS. This is in contrast to ZnS where the ionic radius of Zn^{++} is too small. This is one advantage of alkaline earth sulfides over ZnS. The wide band-gaps and good insulating nature of these materials

further add to their advantages. More recent efforts in color EL displays have therefore focused on alkaline earth sulfide host materials doped with rare-earth activators. A number of research groups around the world have demonstrated that these are very promising devices for multi-color EL displays.

1.3 The purpose of this research

The purpose of this thesis is to develop a quantitative model, which explains the luminescence characteristics of SrS:Ce a.c. thin film electroluminescent display devices. These devices, which use strontium sulfide as a host material and cerium as an activator, have exhibited a luminance as high as 650 cd/m^2 at 1 kHz applied voltage [1] and are considered to be very promising devices for blue electroluminescence displays.

This model is based on the theory developed by Singh, Morton and Gunadisastra [2] - (4]. A computer simulation program in C, is developed to calculate the internal electrical field, the charge transferred in the phosphor

region, and the luminescence produced by impact excitation and by electron ejection from the shallower interface states.

The luminance, field and field was studied for their dependencies on a select few parameters and the results agreed with experimental observations and the theory.

A better understanding of the mechanisms and an experimentally verified model for the operation of SrS:Ce devices can be used to improve the luminescence and efficiency of the devices. Also, they can be used to design new device configurations.

CHAPTER 2

LIGHT EMISSION MECHANISM

2.1 Device Structure

The cross-section view of a simple ACTFEL device is shown in Figure 2.1. It consists of a thick glass, which gives the mechanical support for the device. A film of indium tin oxide (ITO) transparent conductor, which serves as the front electrode of the device, was first coated on the glass substrate.

The substrate is then mounted in a vacuum chamber for deposition of the insulator and active phosphor layers by R.F. sputtering or electron beam evaporation. The pressure in the chamber is under 10^{-6} torr and the temperature is about 150 °C. An insulating layer of aluminum oxide (about 300 nm thick) is first deposited on the ITO transparent conductor. The active phosphor layer (about 600 nm thick) is then deposited. An appropriate quantity of cerium fluoride (0.01 - 1.0 mol.%) is incorporated into the SrS pellet used for deposition. The second insulating layer of

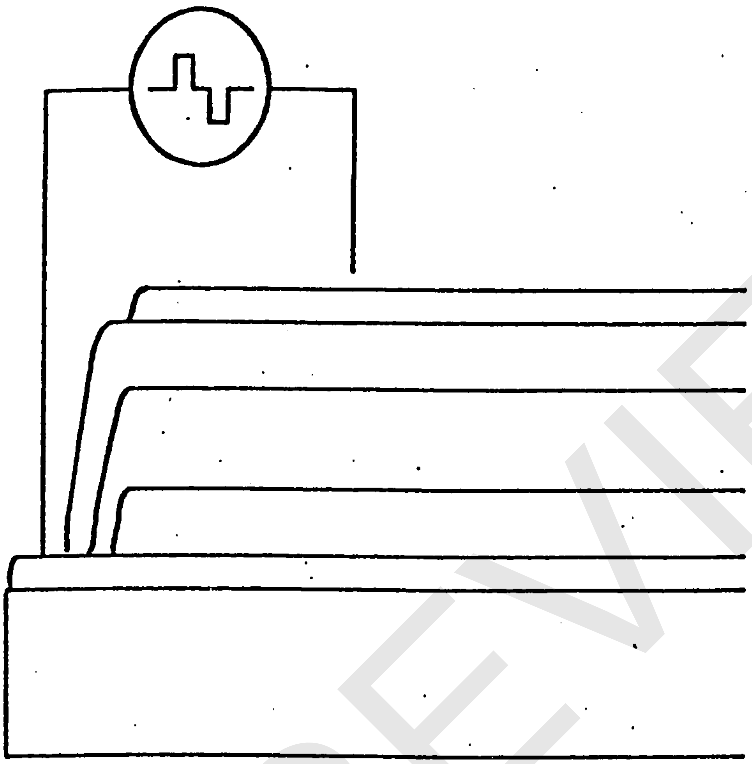

Fig 2.1 Cross section view of ACTFEL device

aluminum oxide (300 nm thick) is then deposited on the phosphor active layer. Finally the back electrode is deposited. Usually an aluminum layer (about 200 nm thick) of 1/8″ diameter dot is used for the back electrode of the testing devices. The back electrode also serves as a reflective layer to increase the efficiency and the luminescence in the desired direction.

The phosphor active layer is surrounded by two dielectric layers, which are aluminum oxide insulator. These two dielectric layers are important to determine the device performance, such as the threshold and breakdown voltage, the efficiency of the device and the luminescence produced by the device.

2.2 Luminescence Characteristics

The luminescence response of the SrS:Ce device to various pulse voltage waveforms was reported by Singh, Morton and Miller [10]. The steady-state luminescence response of the SrS:Ce device to a voltage pulse train of the form of Fig. 2.2 is shown in Fig 2.3.

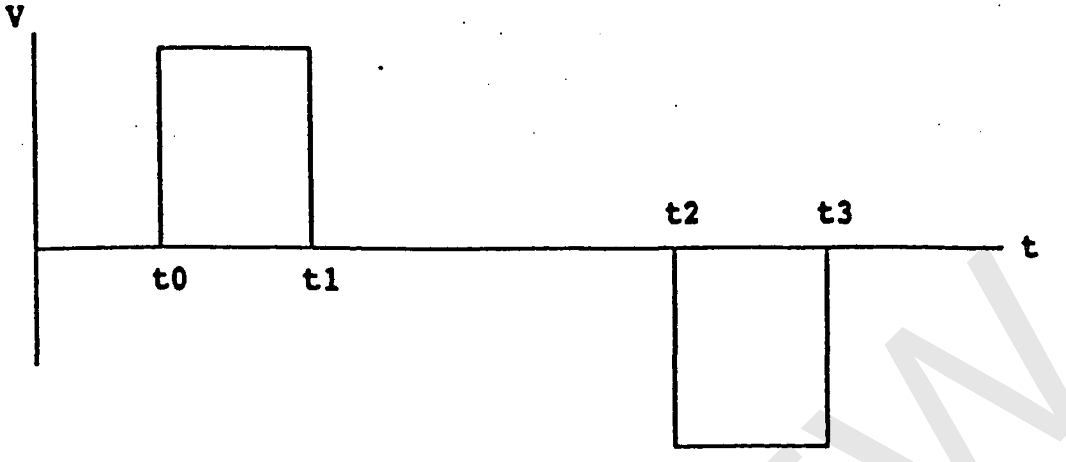

Fig. 2.2 Applied Voltage

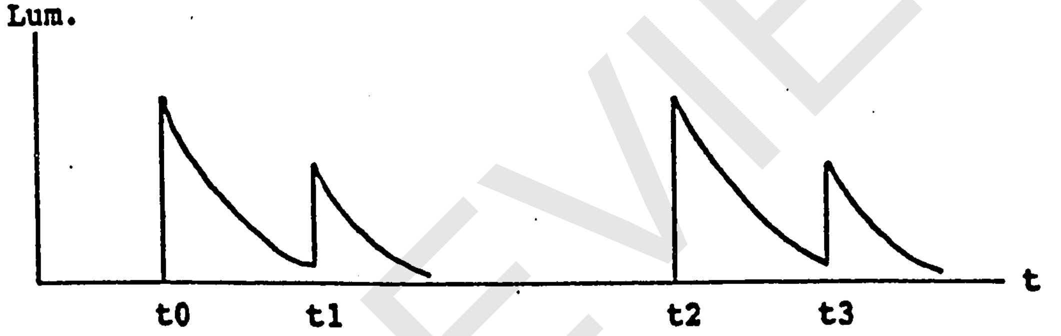

Fig. 2.3 Luminescence of SrS:Ce Device

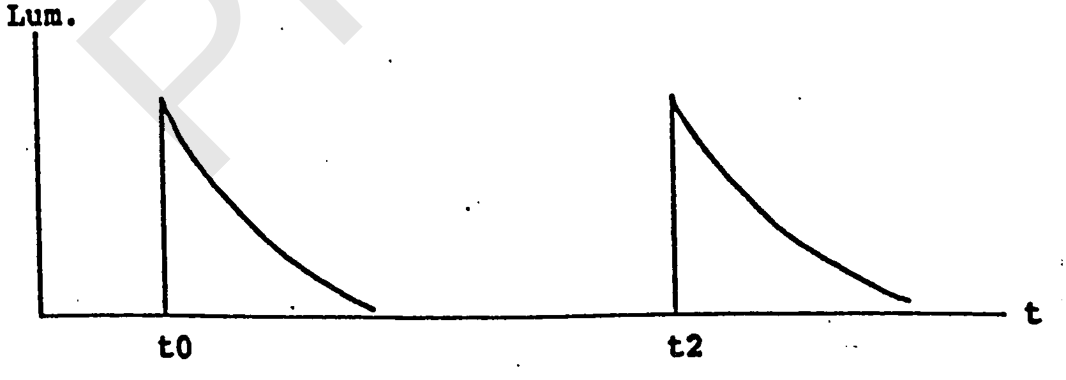

Fig. 2.4 Luminescence of ZnS:Mn Device

Unlike the response of the ZnS:Mn device to the voltage pulse train shown in Fig. 2.4, the luminescence response of the SrS:Ce device showed a peak not only at the leading edge but also at the trailing edge of the excitation voltage pulse. The ZnS:Mn device usually only showed one luminescence peak at the leading edge. In a very few cases, the ZnS:Mn device with high Mn activator concentrations has been reported to have two luminescence peaks [10].

When the driving voltage pulse is applied to the device, the voltage establishes an electric field within the SrS:Ce layer in excess of about 2×10^6 V/cm; electrons will be ejected from the insulator-phosphor interface and the conduction current will flow. This current increases rapidly with the increase of the driving voltage. The electroluminescent emission, which is caused by radiative relaxation of the cerium activator from an excited state to a lower state, seems to be related directly to this conduction current.

In general, an activator needs to meet several requirements. Its cross section for impact excitation should be large to increase the impact excitation of the

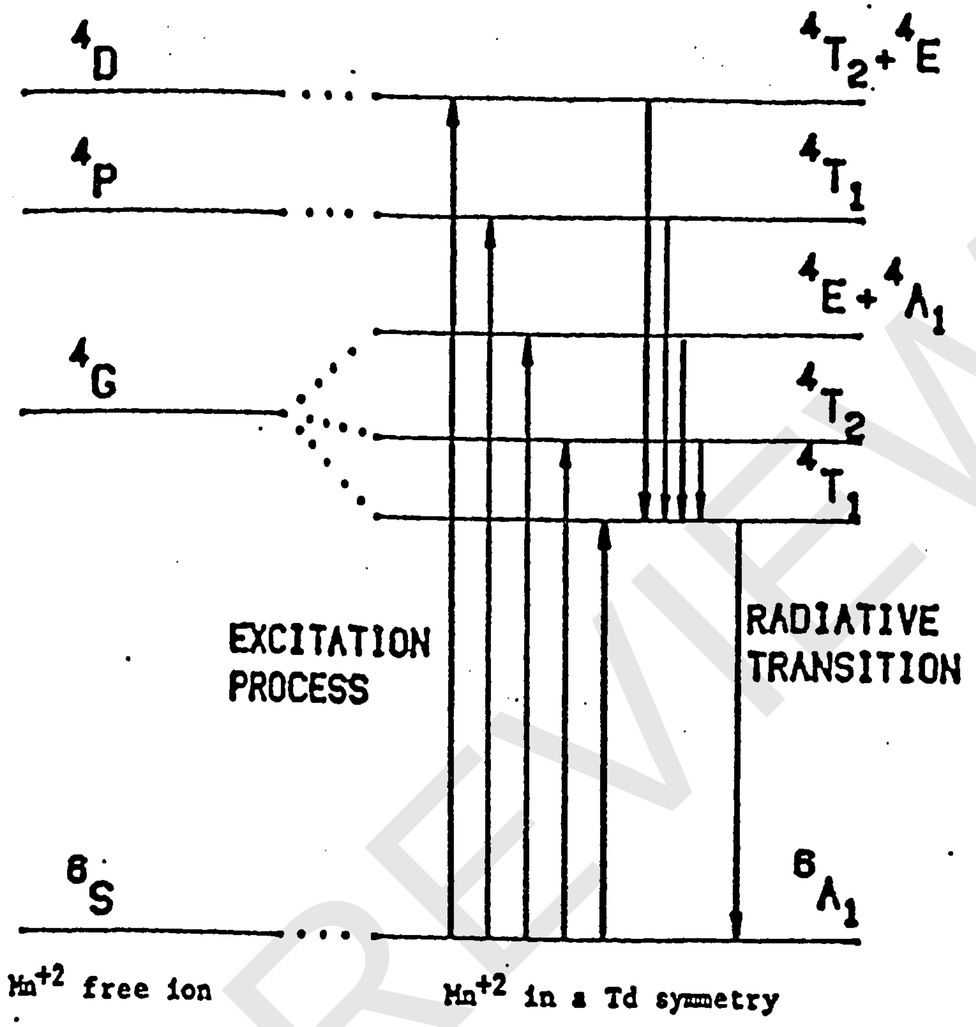

Fig 2.5 Schematic diagram of the Mn^{+2} ion energy level in free space (left) and a cubic lattice environment (right). The arrows indicate the excitation and relaxation transitions.