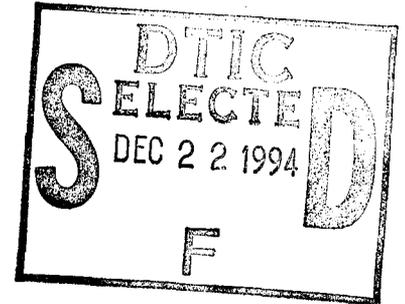


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LOW TEMPERATURE MATERIALS GROWTH AND PROCESSING DEVELOPMENT FOR FLAT PANEL DISPLAY TECHNOLOGY APPLICATIONS

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CHARACTERIZATION AND SIMULATION OF THIN FILM TRANSISTORS FOR TRANSIENT THERMAL PROCESSING

V. S. Rao Gudimetla, Assistant Professor

Introduction

The goal of this phase of the project is to make DC, AC, transient measurements on the TFTs, fabricated by Professor Sigmon and his group at Arizona State University using low temperature processing techniques. From these measurements, SPICE parameters will be extracted and these results will be used for process monitoring and device and process optimization for display applications. This work was started by Rao Gudimetla on 10/1/94 and this technical report covers the period 10/1/94 to 12/1/94. The devices from ASU are expected to be ready in early 1995. Meanwhile, previously obtained measurements on TFTs fabricated at Tektronix Inc. are being used to establish a reliable extraction methodology.

Results

Both n- and p-channel TFTs, obtained from Tektronix Inc., were fabricated in silicon-implanted polysilicon, followed by a long time anneal without any grain boundary hydrogenation. The gate lengths are 12.5 and 5 microns with 100 micron width. S-parameter measurements (which were converted to Y-parameters) were made at several bias points over the frequency range of 300 KHz to 20 Mhz. The following are the key accomplishments.

1. An often suggested AC equivalent circuit for TFTs was used to extract the parameters such as transconductance, gate to source capacitance, gate to drain capacitance, and drain to source capacitance as functions of frequency at different bias points.
2. A detailed analysis for the AC performance of TFTs, developed in the past by the author in the linear and triode regions of I-V data, is being compared with the extracted parameters of the devices and equivalent circuit.

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Immediate Future Plans

1. Comparison of measured and theoretical AC performances will be completed for these devices.
2. Efforts are under way to check if the data on the capacitances can be used to obtain a circuit model to simulate the electrical properties of the grain boundary for use in the SPICE simulations.
3. Recently, some new devices were obtained from XEROX PARC (Professor Berglund). Measurements and similar analysis will be completed for these devices.

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BANDGAP ENGINEERED EL PHOSPHORES

Reinhart Engelmann, Professor
Rajendra Solanki, Associate Professor

Graduate Assistant: John Ferguson

Introduction

During this quarter a research assistant has been hired for the project who has passed all his qualifications for his Ph.D. program. The student has dedicated most of his time to familiarize himself with the various aspects of ALE growth and characterization working directly with a senior research assistant. An important precursor for the CaS growth, i.e. Ca(TMHD), has been obtained and studied.

Specific attention for the planned growth of CdSe/CaS QW phosphors focused primarily on precursor selection and characterization. During the course of our ongoing white phosphor investigation we encountered problems with the Sr precursor, Sr(TMHD), purchased from Strem Chemicals. A particular drawback is thermal instability. For this reason tests have started on thermal stability of the planned Ca precursor for the CaS barrier ALE. Strem is the only vendor who currently sells a similar compound for Ca, Ca(TMHD).

We have acquired this Ca precursor and have been studying its melting behavior. There is a residue left behind during the melting process which possibly could cause major problems in the ALE growth of CaS. Further tests on this residue problem are called for. As an alternative, we also have contacted a number of chemists at several universities in order to obtain another potential source for synthesizing preforms of Sr(TMHD) and Ca(TMHD). We were able to receive a commitment from the University of Helsinki.

As an immediate possible remedy we shall try to purify the available Ca precursor from Strem. A sublimator will be built for this purpose. Then ALE growth of CaS can begin using this Ca precursor.

FIELD EMITTER FLAT PANEL RESULTS

Anthony E. Bell, Associate Professor

Graduate Assistants: Kit-sing Mak, Haibing Liu

Efforts during the last reporting period have been devoted to preparing nanotube graphite filaments of nanometer radii to act as field emitters for field emitter display applications. We believe that the mechanism of the reported diamond field emitters (SI Diamond etc) is not due to emission from diamond negative electron affinity surfaces, although that still may be an interesting possibility, if ways can be found to n-dope diamond.

Our belief is that the reported random emission sites found in diamond flat cathodes is caused by emission from nanotubes of graphite, of the type reported first by Iijima very recently in Nature (356 1991 p6). Since that report there has been an explosion of interest and activity in the preparation and properties of these nanotubes which are related to fullerenes - another form of carbon of much current research interest. These nanotubes consist of rolls of graphite sheets one atom layer thick rolled carpet-like to produce tubes a few hundred angstroms diameter. Depending on preparation methods, the tubes may be completely enclosed with an open end or they may consist of several concentric tubes and they may have closed ends.

Current research work in other laboratories (Annual Review of Material Science(24 1994 235-264) is aimed at increasing the yield of nanotubes and at finding conditions for the production of single wall tubes of diameters in the range 10-20 nm. Open ended tubes appear to grow lengthwise whereas closed ended tubes grow by thickening. Hence the open ended tubes offer two advantages for FEDs: 1. the tubes are thinner and 2. the ends are single atom thickness. Both of these results should produce field emitter sites that emit at less than 100 V.

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Our research has been directed at producing such nanotubes using CVD with butane in hydrogen directed at a substrate at 900 C. We have produced nanotubes on graphite substrates suspended on molybdenum meshes for ease of use in the TEM so that we can examine them at extremely high magnification.

The next step is to examine their field emission properties which we plan to do in a way that will enable us to determine the uniformity of nanotube distribution since this is the key to development of a useful FED cathode.

ELECTROLUMINESCENCE DISPLAY PROGRAM

Rajendra Solanki, Associate Professor

Graduate Assistant: W. Kong

Although commercial electroluminescent(EL) displays have been produced for over a decade, these displays are predominantly monochrome. In order to compete with other flat panel technologies, an extensive effort is directed towards achieving full color EL displays. There are two methods of producing full color electroluminescent flat panel displays; by using (a) three different phosphors, each emitting a primary color or (b) a white light emitting phosphor with three filters, each transmitting a primary color. The objective of our investigation is to pursue the latter approach, i.e., via white light emitting SrS:Ce,Eu EL displays. Atomic layer epitaxy (ALE) is employed to fabricate these devices.

In the last quarterly report, we had discussed the stability problems associated with the strontium diketonate precursor. We have somewhat resolved this issue by acquiring Sr(TMHD)₃ from Planar International. This Sr source is more stable than the one purchased from Strem Chemicals.

Once we had characterized the thermal behavior of Sr(TMHD), a series of depositions were performed to determine the ALE parameters for SrS growth. Since SrS has a high oxygen and moisture affinity, it is not directly grown on an oxide layer. Instead, SrS layer is sandwiched between two ZnS layers. The EL device structure hence consists of the following sequence of thin film layers(on top of the ITO/ATO precoated glass substrate): ZnS, followed by SrS and another layer of ZnS, and finally aluminum oxide.

The first set of SrS EL devices fabricated were Ce doped, where its precursor was Ce (TMHD). We should note that SrS:Ce appears to be the most promising matrix/activator combination for blue light EL emission. These devices emit light in the blue-green region as shown in Fig. 1. However, in practice a blue transmitting filter is used to remove the green emission. Characterization results of the SrS:Ce EL devices are summarized below.

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- The emission spectrum (Fig.1) shows two bands that are attributed to 2D to $^2F_{5/2}$ ($\sim 490\text{nm}$) and $^2F_{7/2}$ ($\sim 560\text{nm}$) transitions due to the splitting of the ground state. At higher Ce concentrations, this splitting is not observed.

- Maximum luminance intensity was at ratio of 10:1 concentration (i.e., one Ce cycle for every 10 SrS cycles). At higher and lower concentrations, the luminance drops significantly. Changing the doping level also shifts the color coordinates. For example, at 15:1 concentration the emission is more blue, but at 5:1 concentration it shifts towards green as shown in Fig. 2 for a set of devices grown under similar conditions. Therefore, one has to compromise between maximum brightness and color purity.

- There is an emission anisotropy with the polarity of the applied pulse. With a positive pulse (i.e., Al electrode grounded) the emission is due to electron impact excitation. However, with a negative pulse, the emission is due to two mechanisms: electron impact and recombination, as shown in Fig. 3. We are investigating this phenomena in further details to understand the cause of the anisotropy.

- The EL emission lifetime is about 10 μs . The short decay time was expected due to the allowed 2D - 2F transitions. The brightest emission recorded was 78 fL (6KHz, 240V).

-From our prior work on ZnS EL devices, we know that post-deposition RTA treatment increases their emission efficiencies. Several time/temperature (400-650 $^{\circ}\text{C}$) cycles were examined for the SrS devices. Our conclusion is that the RTA treatment of SrS EL devices does not enhance their emission. This is illustrated in Fig. 2 for devices #201 and #201a, where sample 201a has been annealed (600c, 30s). There is no significant difference between annealed and unannealed devices. However, we do believe that an anneal cycle in S ambient would most likely enhance the performance of these devices. We plan to examine this at a later time.

The top insulator in these devices is Al_2O_3 , which is deposited using aluminum chloride and water. Since SrS has a high affinity for moisture, we believe that it gets degraded when the top oxide layer is deposited. Therefore, we are in the process of investigating alternatives to water as the oxygen donor. These results will be reported in the next quarterly report.

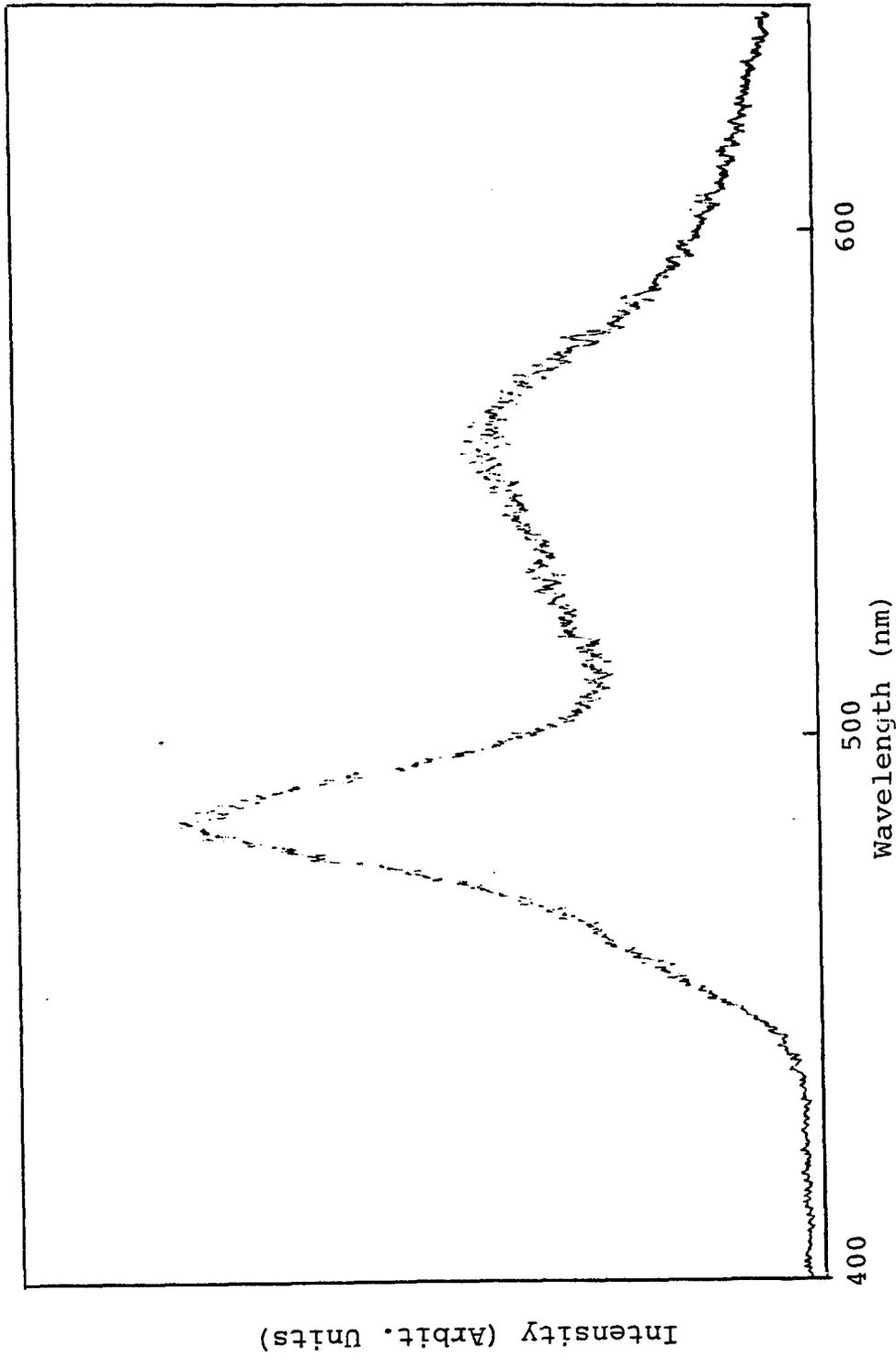


Fig.1. EL emission spectrum of an SrS:Ce device.

1931 C.I.E. Chromaticity Diagram

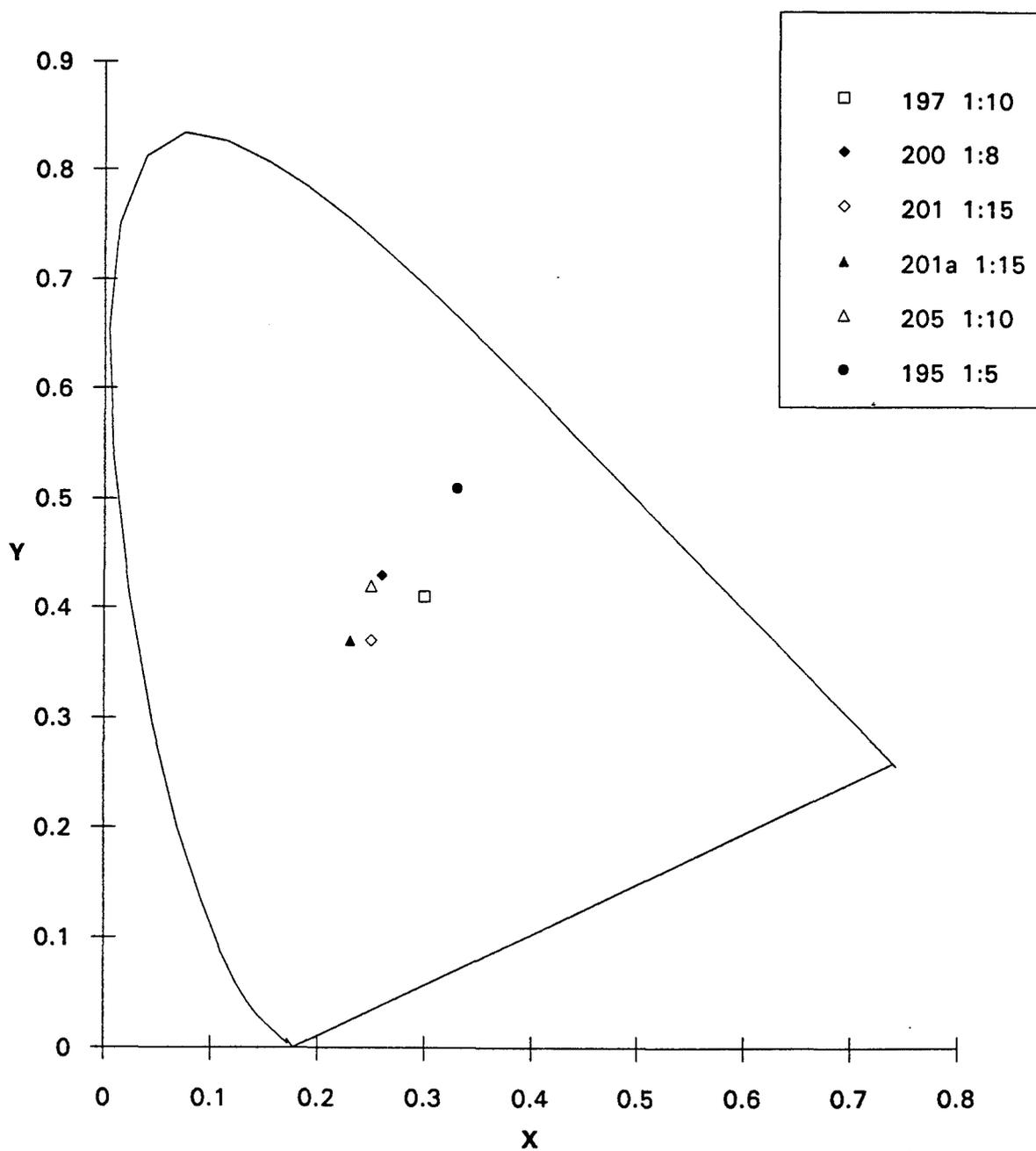


Fig.2. Chromaticity of SrS:Ce EL devices as a function of Ce doping concentration. The chromaticity shifts towards green at higher Ce concentrations.

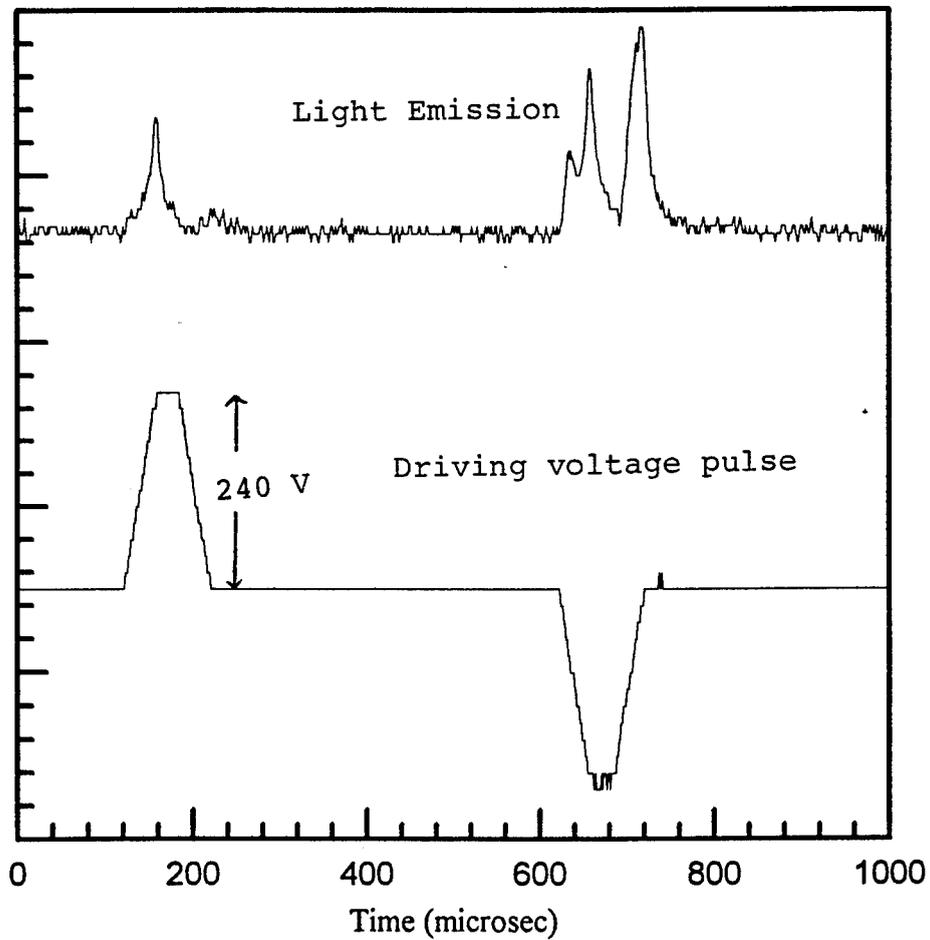


Fig.3. Light emission as a function of the driving voltage pulse showing the anisotropy with the polarity of the voltage pulse.