Flat Panel Displays Topical Conference
Room 604 - Session FP-MoA

Luminescent Thin Films
Moderator: P.H. Holloway, University of Florida

2:00pm **FP-MoA1 Critical Issues Related to Processing and Properties of Laser Deposited Luminescent Oxide Thin Films**, ***R.K. Singh***, *K.G. Cho, D. Kumar, P.H. Holloway,* University of Florida **INVITED**

The performance of the powder-based field emission display devices can be improved significantly by using thin film phosphors due to their higher lateral resolution, better thermal stability, reduced outgassing, and better adhesion to the solid surfaces. A variety of growth techniques such as evaporation, spray pyrolysis, sputtering, metal organic chemical vapor deposition, and pulsed laser deposition, are employed for the fabrication of thin film phosphors. The pulsed laser deposition (PLD) technique is emerging as one of the most convenient techniques to fabricate complex thin films since it offers numerous advantages, including convenient reproduction of target stoichiometry onto the films, low contamination level, high deposition rate, atomically sharp step coverage, thickness control. However, the biggest hindrance in the use of thin film phosphors is their low brightness and efficiencies in comparison to those of bulk powder phosphors. In this talk, we will discuss some of the critical issues related to processing and properties of laser deposited Eu-activated yttrium oxide (Eu:Y @sub 2@ O @sub 3@) luminescent thin films. We will also present our results showing how brightness and stability can be improved significantly by changing microstructure, orientation, and crystallinity of Eu:Y@sub 2@O@sub 3@ films by changing the processing parameters during pulsed laser deposition. A theoretical model will be presented to account for the increase in brightness with an increase in film roughness which has been found to be a key parameter determining the light piping effect.

2:40pm **FP-MoA3 The Effect of Carbon Deposit on Electron Beam Degradation of Oxide Thin Film Phosphors**, ***C. Kondoleon***, *B.L. Abrams, J. Thomes,* University of Florida*; P. Rack,* Rochester Institute of Technology*; V. Krishnamoorthy, P.H. Holloway,* University of Florida

The cathodoluminescence (CL) brightness and spectral distribution from thin film Ta@sub2@Zn@sub3@O@sub8@ has been studied as a function of electron dose. Thin films of Ta@sub2@Zn@sub3@O@sub8@ were prepared by sputtered deposition followed by rapid thermal annealing (RTA). Under bombardment by 2keV electrons, the films produce a blue luminescence with a dominate wavelength of 386nm. These films were exposed to residual vacuum gas dominated by H@sub2@ and H@sub2@O at pressures ranging from 10@super-8@ Torr to 10@super-6@ Torr with <5% loss in CL brightness. However when hydrocarbons from colloidal graphite paint was introduced and raised the base pressure of the vacuum from 1 x 10@super-8@ Torr to 8 x 10@super-8@ Torr, the CL brightness was degraded to 5% of its original value after approximately 4 hours at 2.7 x 10@super-4@ A/cm@super2@ (corresponding to a dose of 3.9 C/cm@super2@). The electron beam stimulated degradation since when the beam was off, degradation stopped. In addition, on some samples the electron beam was blocked by a Cu grid over the surface and degradation only occurred when the electron beam struck the surface. Auger analysis showed a thick layer of carbon. It is speculated that the electron beam cracked hydrocarbons, resulting in deposition of a carbonaceous layer which attenuated primary electrons and absorbed luminescent photons. The significance of this phenomena in field emission displays will be discussed. This work is supported by DARPA Grant MDA 972-93-1-0030, through the Phosphor Technology Center of Excellence.

3:00pm **FP-MoA4 Blue Luminescence Properties of Zinc Oxide Doped with Low Concentration of Tungsten**, ***J.B. Sobti***, *V. Bhatia, P.M. Babuchna, M.H. Weichold,* Texas A&M University

Research in developing high quality thin film phosphors for field-emission displays (FEDs) has gained momentum over the last decade. From the aspect of low voltage applications, cost and durability, efficient red and gren phosphors are now available. However, phosphors for blue light still need improvement. An investigation conducted at Texas A&M University showed that tungsten doped zinc oxide (ZnO:W) emits blue light at 490 nm when excited at 300V.@footnote 1@ Results for this phosphor preparation, its luminescence and material characterizations, and potential use in fabricating a FED are prsented in this paper. Using ion mill, thin films of ZnO and W were co-deposited. The films with varying W concentrations (10%, 30%, and 50%) were annealed at 450°C, 650°C, and 850°C for 4, 8, and 12hrs in the presence of argon and oxygen. Luminescent characterization of these films indicated that phosphor having 10% W, annealed at 850°C for 12 hrs. in pure argon emitted the brightest blue light.@footnote 2@ Continuing research involves studying the effect of even lower W concentrations under above-mentioned conditions. Radiance data for ZnO:W phosphor will be measured and compared with the efficiencies of other blue phosphors. X-ray diffraction studies and infrared spectroscopy of the films showed formation of zinc tungstate (ZnWO@sub 4@), which has been reported to exhibit photoluminescence at 490 nm. This led us to conclude that ZnWO@sub 4@ is the source of blue light from our phosphor.@footnote 3@ This paper also presents results from Stokes shift measurements to understand mechanisms for blue light emission. Research is underway in determining a material chemically compatible with the phosphor to form anode lines for the display. Results from this research will also be reported. @FootnoteText@ @footnote1@Technology Disclosure to TAMU Technical Licensing Office (1993). @footnote 2@J. B. Sobti et al, April 1998, AVS Texas Chapter meeting. @footnote 3@J. B. Sobti et al, Spring, 1999, MRS meeting.

3:20pm **FP-MoA5 Progress in TFEL Technology**, ***S.-S. Sun***, Planar Systems, Inc. **INVITED**

This paper will review the basic operation of inorganic TFEL displays. Recent progress in monochrome and color TFEL phosphors including the new efficient blue TFEL phosphor will be presented. The application of these improved phosphors in direct view and active-matrix TFEL displays, both monochrome and color versions, will be described.

4:00pm **FP-MoA7 Multicolor Emitting TFEL Devices using Ga@sub 2@O@sub 3@ Phosphors Co-doped with Mn and Cr**, *T. Minami,* ***T. Nakatani***, *T. Miyata,* Kanazawa Institute of Technology, Japan

This paper introduces newly developed TFEL devices consisting of Mnand Cr-co-doped Ga@sub 2@O@sub 3@ phosphor thin-film emitting layers combined with a thick BaTiO3 ceramic sheet insulating layer. The co-doping effects of Mn doped into Ga@sub 2@O@sub 3@:Cr thin films and Cr doped into Ga@sub 2@O@sub 3@:Mn thin films on their electroluminescent properties have been investigated. Ga@sub 2@O@sub 3@:Mn,Cr phosphor thin films were prepared using a solution coating technique. The Mn and Cr dopant contents (Mn/(Mn+Ga) and Cr/(Cr+Ga) atomic ratios) were varied from 0 to 20 atomic%. In order to improve the EL characteristics, all deposited Ga@sub 2@O@sub 3@:Mn,Cr phosphor thin films were post-annealed in an Ar atmosphere for 1 h at 1020@super o@C. The emission from Ga@sub 2@O@sub 3@:Mn,Cr TFEL devices was more strongly dependent on the Cr content than on the Mn content doped into the phosphor emitting layers. A high luminance above 100 cd/m@super 2@ was obtained in all TFEL devices using Ga@sub 2@O@sub 3@:Mn,Cr thin films co-doped with a Cr content from 0 to 20 at.% and a Mn content of 0.3 at.% when driven at 1 kHz. The emission color from these Ga@sub 2@O@sub 3@:Mn,Cr TFEL devices changed from green to red emission as the co-doped Cr content was varied from 0 to 20 at.%. In addition, the emission color changed from green to red as the applied voltage was increased. Thus, Ga@sub 2@O@sub 3@:Mn,Cr TFEL devices would be useful in color indicators and displays, with color controlled by the applied voltage.

4:20pm **FP-MoA8 Effect of Ce@sub 2@O@sub 3@ and Ag/Cu Codoping on the Brightness and Efficiency of RF Magnetron Sputtered ZnS:TbOF Alternating Current Thin Film Electroluminescent Displays**, *J.P. Kim,* ***D.J. Moorehead***, *K.E. Waldrip, B. Speck, M. Davidson,* University of Florida*; P.H. Holloway,* University of FLorida*; Q. Zhai,* University of Florida

ZnS:TbOF has shown promise as a green electroluminescent phosphor, but it still lacks the performance necessary to incorporate it into a commercially viable ACTFEL device. Many codopants have been shown to improve the performance of such devices. This study reports the results of Ce@sub 2@O@sub 3@ and Cu/Ag codoping on the brightness and efficiency of ZnS:TbOF thin film EL devices. As-deposited Ce codoped ZnS:TbOF films showed no significant change in brightness. Annealing of low Ce concentration half-stack (no top dielectric) devices improved EL brightness by 65% over the best undoped samples. Scanning electron microscopy shows no significant morphology changes in annealed films. Ag/Cu codoping did not dramatically effect the brightness of as-deposited films, but there were significant improvements in BV characteristics of annealed samples. Half-stack data show a much sharper turn-on and B20 improvement from 32 cd/m2 to 70 cd/m2. Samples annealed at high-temperature (850°C) demonstrated severe degradation in brightness and

efficiency, while SEM micrographs show that grain size significantly decreased, possibly due to precipitation of another phase.

4:40pm **FP-MoA9 A Comparison of the Short Wavelength Performance of ZnS and SrS Thin-Film Electroluminescent Devices via a Rare Earth Doping Study**, *P.D. Keir,* ***C.M. Maddix****, B. Baukol, J.F. Wager, B.L. Clark, D.A. Keszler,* Oregon State University

The short wavelength electroluminescent (EL) performance of SrS and ZnS phosphors for thin-film EL flat-panel display applications is compared. This is accomplished by measuring the EL spectra of ZnS and SrS EL devices doped with various rare earth luminescent impurities: Dy, Er, Ho, Tb, and Tm. All of the SrS EL devices tested have more intense EL emission at short wavelengths than corresponding ZnS EL devices. Additionally, all of the SrS EL devices operate at smaller average phosphor fields. The superior EL performance of SrS appears to be due to a hotter electron distribution and to the presence of positive space charge in SrS EL devices. The ZnS devices show a distinct EL cut-off at ~440-460 nm. This is attributed to an inadequately heated electron distribution which is unable to excite high energy transitions in the luminescent impurity. Collectively, these results indicate that efficient blue emission from a ZnS phosphor is unlikely.

5:00pm **FP-MoA10 Role of Cations and Anions in Donor Doping of ZnS:Mn Thin Film Electroluminescent Phosphors**, ***K.E. Waldrip****, J.S. Lewis, III, Q. Zhai,* University of Florida*; M. Puga-Lambers, M. Davidson,* University of Florida, Microfabritech*; P.H. Holloway,* University of Florida*; S.-S. Sun,* Planar Systems, Inc.

Alternating current thin film electroluminescent ZnS:Mn phosphors have been deposited by RF magnetron sputter deposition on glass substrates coated with indium tin oxide (ITO) transparent conductor and an alumina-titania (ATO) composite dielectric. A co-dopant was introduced by an ex-situ diffusion method. The top dielectric and contact layers were deposited to complete the device. Control samples were processed exactly the same, with the exception that the co-dopants were not introduced. Co-doping ZnS:Mn thin film electroluminescent phosphors with potassium chloride resulted in a 50% increase in brightness and efficiency (150fL, 1.9L/W vs. 100fL, 1.3L/W), a 5% increase in threshold voltage, and an improvement in brightness vs. voltage stability. Electrical analysis revealed increases in the amount of transferred charge, leakage charge, internal phosphor field, and in the overall symmetry of the electrical characteristics with respect to applied voltage pulse polarity with KCl co-doping. The observations to date of the improved performance in co-doped ZnS:Mn can be explained by a donor doping mechanism in which chlorine acts as the shallowest and most abundant donor in the phosphor film. Interstitial potassium also behaves as a donor, and the theory rests on the assumption that there are more activated donors than acceptors. The purpose of the work presented here is to elucidate the role of the cation and the anion in the improved performance of co-doped ZnS:Mn phosphors. KF, KCl, KBr, LiCl, NaCl, ZnCl@SUB 2@ and K@SUB 2@S were tested as dopants to deconvolute the roles of the anion and the cation. The brightness and efficiency vs. voltage and threshold voltage for each sample will be reported against the control samples. SIMS and XTEM, as well as spectral distribution and electrical analysis will also be presented and correlated with the donor doping theory.

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