Tuesday Morning, October 26, 1999

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

Novel Materials for Field Emission Displays and Technologies for Flexible Displays

Moderator: B. Gnade, DARPA

8:20am **FP-TuM1 Comparative Study of Field Emission from Microcrystalline Graphite, Nanostructured Graphitic Films, and Nanotubes**, ***A.A. Talin***, *K.A. Dean, B.F. Coll, J.E. Jaskie, M. Johnson,* Motorola Flat Panel Display Division

Electron emission at remarkably low electric fields has been reported from a wide variety of carbon films over the past decade. Although the precise mechanism of emission is still under debate, it is becoming clear that graphitic phases of carbon play a central role in the origin of the low-field emission properties of carbon-based cold cathodes. In this work, we use conventional diode type apparatus to measure broad-area emission characteristics, and field emission microscopy to investigate and identify the carbon phases associated with field emission. We demonstrate that purely SP2 carbon films can be excellent field emitters. We relate the differences in broad area field emission characteristics and in field emission microscopy images in terms of film morphology and the field emission physics of various carbon phases. .

8:40am **FP-TuM2 Demonstration of Low Work Function Cu-Li Alloy Coatings for Edge Field Emission Devices@footnote *@**, ***J.C. Tucek***, *A.R. Krauss, O. Auciello, D.M. Gruen, D.C. Mancini, N. Moldovan,* Argonne National Laboratory

Low work function alkali metals have been shown to significantly enhance field electron emission when used as coatings for microtip field emission arrays (FEAs). Maximum enhancement of electron emission is expected for alkali metal coatings 0.5-1 monolayer in thickness. However, alkali metals are both physically and chemically unstable in layers exceeding a few Å in thickness, and therefore, it is extremely difficult to fabricate and maintain, during operation, such thin layers on FEAs. We have recently demonstrated that lithium alloy coatings based on materials developed at Argonne National Laboratory provide very stable, low work function coatings with low threshold field (~ 3 V/μm) and enhanced electron emission for application to FEAs.@footnote 1@ These alloy coatings maintain a segregated monolayer of lithium on the surface of the alloy, even under adverse environmental conditions or ion bombardment. As an extension of this work, Cu-Li coated edge emitters are produced by coating Si posts, followed by ion beam sputtering of the alloy and a selective etching of Si, resulting in the formation of hollow cylinders with nanometer thick Cu-Li walls. It can be expected that Cu-Li edge emitters will provide a larger emitter area, and therefore should be more robust than the Si FEAs while maintaining a similar low field emission threshold. In addition, we have performed tests using a simulated flat panel display configuration, which provide information about the emission uniformity of these edge emitters. The emission characteristics of the new Cu-Li-based edge emitters will be discussed in relation to the alloy composition and the geometry of the emitters. Re abstract entitled "Demonstration of Low Work Function Cu-Li Alloy Coatings for Edge Field Emission Devices" by J.C. Tucek et. al., submitted for presentation at the 46th International Symposium of the American Vacuum Society, Seattle, Washington, October 25-29, 1999, please be advised that: The submitted manuscript has been created by the University of Chicago as Operator of Argonne National Laboratory ("Argonne") under Contract No. W-31-109-ENG-38 with the U.S. Department of Energy. The U.S. Government retains for itself, and others acting on its behalf, a paid-up, nonexclusive, irrevocable worldwide license in said article to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government. @FootnoteText@ @footnote 1@ O. Auciello, et. al., J. Appl. Phys. (in press, 1999). @footnote *@ Work supported by the U.S. Department of Energy, BES-Material Sciences, under Contract W-31-109-ENG-38 and DARPA/ONR under contract N00014-97-F0905.

9:00am **FP-TuM3 Progress and Performance of FEAs using Zirconium Carbide Field Emitters**, ***W.A. Mackie***, *T. Xie, P.R. Davis,* Linfield Research Institute

Field emission arrays are finding many and varied applications from the present use in flat video displays to potential uses in microwave devices, and spacecraft charge dissipation and propulsion systems. Many of these proposed uses would require high currents per tip and operation in adverse vacuum conditions. These requirements necessitate robust cathode materials. Our work focuses on the use of transition metal carbides for field emission sources. Here, we report on vapor deposition of zirconium carbide emitter cones in the conventional field emission array geometry. Generally, we have used array blanks provided by others with 50,000 gates. We deposit these carbide emitters via physical vapor deposition from crystalline zirconium carbide sources. Use of this material has required changes in the array fabricating technique used by others due to the high temperature needed for evaporation. We will report on results of studies using several new materials for the lift-off layer and the processing steps needed for proper cone formation using zirconium carbide. The emission properties of arrays formed in this was will also be reported. In general, zirconium carbide has an electronic work function approximately 1 eV lower than molybdenum, a common FEA emitter material. This has translated into a measured lowering of turn-on voltages by 45% and an increase in emission stability. Extraction voltages in the 35-65 volt range are reported for solid carbide emitter cones in the FEA geometry. Emission at relatively high individual tip currents and at poor vacuum levels will also presented and discussed. These carbide cone arrays could lead to extremely robust electron sources and open the use of FEAs to a variety of applications. Work supported in part by DARPA High Definition Systems Initiative under ONR Grant No. N00014-96-1-1011.

9:20am **FP-TuM4 High-Speed Assembly of Flexible Film LCDs: Materials and Process Development**, *J.T. Richard,* Polaroid Corp.*;* ***W.K. Smyth***, Polaroid Corp., U.S. **INVITED**

Thin, flexible displays have long been considered ideal for portable display applications where weight, ruggedness and product packaging are critical performance criterion. Materials research and display assembly process development targeting flexible displays have resulted in low volume plastic display production using new materials on typical LCD production lines with comparable throughput. In order for flexible displays to become pervasive in the portable applications, new materials, equipment and processes which take advantage of high speed and low cost web assembly techniques will be required. As part of ongoing optical films research at Polaroid, new materials and processes have been developed which improve the performance of flexible displays as well as increase the potential throughput of production volume display manufacturing. A conductor film has been developed which incorporates a high temperature, low birefringence substrate and hard-coat with a thin film optical structure. The unique structure of the sputtered layers integrates high optical transmission, high electrical conductivity, and the ability to be directly patterned with commercially available, IR laser patterning equipment. This thin, durable film can be patterned in continuous rolls to enable web based display assembly. Conventional display assembly processes for edge seal and alignment layer curing and vacuum filling of liquid crystal have prohibitively long cycle times to be feasible for roll to roll display assembly. Fast curing edge seal adhesive and process conditions suitable for web based coating and drying of alignment layers have been developed. In addition, a novel display assembly process, which eliminates the need for vacuum filling, has been demonstrated.

10:00am **FP-TuM6 Growth of ITO and SiN@sub x@ Films on Polymeric Substrates For Flexible Displays**, ***P.F. Carcia***, *R.S. McLean, M.H. Reilly,* DuPont Central Research and Development

The discovery that classes of polymeric materials are electro-luminescent and the rapid progress in their development into a technology promise a revolution in future flat panel displays. Currently, the first devices are being manufactured on glass substrates. If, however, devices could be made on flexible polymeric substrates in a reel-to-reel process, this would reduce cost, improve ruggedness, and reduce weight. However, to achieve success on plastic substrates, barrier coatings are needed to exclude atmospheric gases that chemically degrade device performance, and low resistance transparent coatings are needed for efficient electro-optical performance. In this paper we investigate the relationship of the polymeric substrate and its surface morphology to the properties and structure of inorganic thin films, as examined by atomic force microscopy. Conducting ITO films were grown by rf magnetron sputtering and SiN@sub x@ films by both rf magnetron sputtering and ECR PECVD. ITO films had very small grain size, as deposited on unheated PET and PEN polymeric substrates, 2 mils thick , with sheet resistance of only about 15 ohms/square. These films were relatively thin (150-200 nm thick) with low stress and high optical transparency in the visible, and they were also surprisingly good barriers to oxygen transport. Because of their higher optical transparency, SiN@sub x@ films are more attractive in flexible polymer display devices as barriers for atmospheric gases. And SiN@sub x@ films 50 nm thick, synthesized by

ECR PECVD on PET and PEN film, were excellent barriers (<0.005 cc/m@super 2@/day-atm) to atmospheric gases. Finally, we will discuss a simple method to semi-quantitatively image defects in barrier films.

10:20am **FP-TuM7 Transparent and Conductive Ultra-barrier Coatings for Flexible Plastic Displays**, ***C.I. Bright***, Delta V Technologies

One of the major issues limiting fabrication and lifetime of flexible displays is the moisture and oxygen permeability of the polymeric substrates. The acceptable value of permeation depends on the sensitivity of the particular display technology. Another flexible displays issue is the low temperature capability of optical quality plastic substrates. This restriction on process temperatures has many implications in display fabrication. One example is the low conductivity of the Transparent Conductive Oxide (TCO) used for the necessary transparent electrode layer. An organic layer deposited by the Polymer MultiLayer (PML) process for vacuum evaporation of organic monomers and in-situ e-beam or UV polymerization has demonstrated excellent smoothing of substrate surfaces. When dielectric layers of Al@sub 2@O@sub 3@ or SiO@sub 2@ are combined with PML deposited organic polymer layers; outstanding barrier properties are achieved on flexible plastic film substrates. A PML base coat layer also should provide a clean smooth surface for bonding and nucleation of a deposited TCO. In this work, we combined a PML base coat and a TCO layer to form a transparent conductive barrier where the TCO functions as both the moisture and oxygen barrier, and the required transparent electrode for the display. Multiple pairs of polymer/TCO layers can be used to increase both barrier performance and conductivity, as needed, for a particular display technology. The experimental results for ITO sputtered directly onto a PET substrate, and with a PML acrylic base coat, in a roll-to-roll (web) coating process are reported. The optical, electrical and barrier properties for both constructions were measured and compared. Very preliminary barrier results show permeation values of 0.05 - 0.005 O@sub 2@ cc/m@super 2@/day, H@sub 2@O g/m@super 2@/day, for single layer ITO on a PET (0.007" thick) substrate.

10:40am **FP-TuM8 Fabrication of OLED Devices on Flexible, Ultra-barrier Plastic Substrates**, ***G.L. Graff***, *M.E. Gross, P.A. Mounier, M.K. Shi, M.G. Hall,* Battelle Pacific Northwest National Laboratory*; J.J. Brown, J.K. Mahon,* Universal Display Corporation*; C.I. Bright,* Delta V Technologies*; P.E. Burrows,* Princeton University

To develop displays on flexible polymeric film substrates, transparent ultra-barriers to oxygen and moisture must be provided. The acceptable value of permeation will depend on the sensitivity of the particular display technology. A multilayer film structure with alternate layers of organic polymer and metal oxide, has demonstrated oxygen and moisture permeation rates below the measurement limit of commercial instrumentation (<0.005 O2 cc/m2/day, H2O g/m2/day). This highly transparent, multilayer ultra-barrier coating was deposited by roll-to-roll compatible, vacuum deposition processes. The Polymer MultiLayer (PML) process for vacuum evaporation of organic monomers and in-situ polymerization, was used to deposit the organic layers. DC reactive magnetron sputtering was used to produce the aluminum oxide barrier layers. A transparent conductive coating of ITO was sputter deposited over these ultra-barrier layers to provide a transparent electrode for display construction. Typical performance for a 135 nm thick ITO layer, deposited on a double hardcoated PET (7 mil thick) substrate with ultra-barrier layers, was = 85%T and = 70 ohms/square. OLED devices have been fabricated using the flexible, ultra-barrier substrates, and preliminary device performance will be reported.

11:00am **FP-TuM9 Photoisomerization and Photo-induced Alignment of Azobenzene Containing Dyes and Polymers in Ultrathin Films Fabricated by the Alternate Polyelectrolyte Deposition (APD): Application for LC Displays**, *R.C. Advincula,* University of Alabama at Birmingham, US*;* ***M.-K. Park***, University of Alabama at Birmingham*; A. Baba, F. Kaneko,* Niigata University, Japan

The incorporation of a photochromic moiety in polymers is very attractive due to the possibility of creating new light-sensitive materials and optical devices. Ultrathin films containing photoisomerizable moieties, e.g. azo dyes are excellent materials for inducing control in LC molecules (command layer effects), holographic surface relief gratings, optical storage media, nanoscale applications, etc. In this work we have employed the alternate polyelectrolyte deposition (APD) on solid substrates to fabricate ultrathin films containing photoactive azobenzene groups. We investigated the combination of polymer containing azobenzene dye (PAZO)/ polycation (PDADMAC or PDDA) system and the small molecule dye Direct Red 80/PDADMAC system at various layer thicknesses. The uniform layer by layer assembly of the films was determined by UV-vis spectroscopy, ellipsometry, X-ray reflectivity, QCM, AFM, and SPS. The complex photoisomerization behavior reveals the importance of layer ordering, azobenzene mobility, and aggregation states in determining the future utility of these films. We utilized polarized UV-light to induce photoisomerization and photo-alignment of these ultrathin films. Hybrid LC Cells reveal in-plane homogeneous alignment. Correlation was made on the effect of film formation parameters to the overall film quality and layer ordering. We observed high anisotropies dependent on the dye, layer preparation, thickness, etc. LC Cells made from 5 CB reveal read/write capabilities dependent on the thickness and irradiation parameters. Future possibilities for LC and Large area display device modifications are envisioned.

11:20am **FP-TuM10 Plastic Liquid Crystal Displays from Conducting Polymer**, ***R. Shashidhar***, Naval Research Laboratory*; L. Huang, C. O'Ferrall,* Geo-Centers Inc./Naval Research Laboratory*; W. Fritz, J. Doane,* Liquid Crystal Institute **INVITED**

In a conventional liquid crystal display device (LCD), glass substrates coated with an indium tin oxide (ITO) layer are typically used for the application of an electric field to the liquid crystal material. For many applications, there is a need for a LCD with a plastic substrate. Polypyrrole is a well known conducting polymer for its high conductivity and chemical stability. Compared with the currently used ITO conducting layer, polypyrrole is more compatible mechanically with plastic. Because it is an organic material, it should be able to bend and flex with the substrate. Here we describe the preparation of polypyrrole films on a polyethylene terephthalate (PET) substrate by an in-situ solution deposition process and their patterning by conventional photolithography techniques. We will discuss their important physical properties, such as surface resistance and optical transmission and their suitability as a substitute for ITO as an electrode for a plastic reflective Cholesteric reflective LCD. We have demonstrated for the first time the operation of a fully multiplexed plastic (LCD) using conducting polymers (on plastic) as the substrates and the reflective cholesteric display technology. The resultant display has several features like lightweight, low power consumption, increased ruggedness, bistability, sunlight readability and flicker-free operation. The functioning of the conducting polymer-based LCD is demonstrated and the features that make it attractive for many applications are discussed.

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