Thursday Afternoon, October 23, 2008

Thin Film
Room: 302 - Session TF-ThA

Thin Films for Displays and Flexible Electronics
Moderator: J. Grace, Kodak

2:00pm **TF-ThA1 Thin Film Challenges for Flexible Displays and Electronics**, ***R. Ma***, *M. Hack, J. Brown*, Universal Display Corporation **INVITED**

In this paper, after a brief review of the history and current status of flexible displays and electronics, we will discuss in detail the development of one of the most challenging devices, a flexible full color active matrix organic light emitting diode (OLED) display. We will focus in the three areas: ultra-thin flexible TFT backplanes, rugged thin film barrier protection, and the flexibility of the overall system. The use of flexible substrates generates two main challenges: the handling of the flexible substrates and the compatibility of TFT process to substrate property. Both semiconductor and TFT-LCD industries are built on rigid substrates so the traditional process can't be applied directly to flexible substrates. Mis-match of thermal properties between substrates and TFT materials/process will result failed backplanes. We have chosen thin metal foils as the substrates for flexible displays because of their excellent thermal, mechanical and permeation barrier properties and good flexibility. Metal foils as thin as 25 mm have been used and planarization process has been developed. Another key challenge is to develop a flexible thin film permeation barrier. OLEDs degrade as a result of exposure to atmospheric oxygen and water. Working with Professor Wagner's team at Princeton University, we have identified a flexible, highly impermeable barrier layer that is deposited from environmentally-friendly and inexpensive precursors in a single-chamber reactor. The lifetime of OLEDs encapsulated with the layers exceeds the industrial target of 1,000 hours and also the lifetime of conventionally sealed glass packaged OLEDs. Many materials are used in a flexible AMOLED: organic, inorganic and metallic systems. We have studied the characteristics of such materials and developed an initial system to study the mechanical flexibility of the integrated device. We will present the required material building block properties and present recent results on ultra-thin (< 50 µm) flexible OLED displays. Flexibility results on these displays show that they operate when conformed to a tight diameter of only 5 mm.

2:40pm **TF-ThA3 Roll-to-Roll Plasma Enhanced Chemical Vapor Deposition of Graded Ultra-high Barrier Coatings on Polymer Substrates**, ***M. Yan***, *R.A. Zhao, D.J. Smith, C.L. Jones, P.A. Mcconnelee, A.G. Erlat, A.R. Duggal, T.P. Feist*, GE Global Research

The use of plastic film substrates for organic electronic devices promises to enable new applications, such as flexible displays and conformal lighting, at low cost through high volume roll-to-roll fabrication. Unfortunately, presently available substrates cannot yet deliver this promise because of the challenge in achieving the required combination of optical transparency, impermeability to water and oxygen, mechanical flexibility, and high temperature capability. In this contribution, we describe our roll-to-roll (R2R) plasma enhanced chemical vapor deposition (PECVD) process development and performance of a unique graded transparent ultra-high gas barrier coating on top of plastic substrate which is aimed at meeting this challenge.

3:00pm **TF-ThA4 Latest Innovations in Large Area Web Coating Technology via PECVD Source Technology**, *M.A. George, J.E. Madocks, J. Morris,* ***H. Chandra***, General Plasma

In this paper we discuss the latest results of our development of large area PECVD source technologies for flexible substrates. A significant challenge for flexible displays is the economical application of thin films for use as vapor barriers, transparent conductive oxides, optical interference thin films and thin film silicon. Here at General Plasma we have developed two innovative PECVD source technologies that provide an economical alternative to low temperature sputtering technologies and enable some thin film materials not accessible by sputtering. The Penning Discharge Plasma (PDP™) source is designed for high rate PECVD depositions on insulating temperature sensitive web.[1] This technology has been utilized to deposit SiO2 and SiC:H for barrier applications.[2] The Plasma Beam Source (PBS™) is useful for deposition on conductive or rigid substrates or for deposition of thin films that are sensitive to the high ion bombardment flux inherent to the PDP technology. We have developed thin film processes in our laboratory for deposition of SiO2, SiC:O, SiN:C, SiN:H and thin film silicon via this PBS source.[3] We discuss the patented source design, plasma physics and chemistry of the deposited thin films.

[1] J.Madocks; "High Rate PECVD Source for Flexible Substrates", Proceedings of the Society of Vacuum Coaters, pp 187, 2003.

[2] V. Shamamian, L. Zambov, U. Pernisz, S. Kim, S. Perz and G. Cerny, "Progress in the Development of SiC:H Alloy Film on Flexible Substrates for Extremely Low Moisture Permeability Applications", Proceeding of the Flexible Displays and Manufacturing Conference, 2006.

[3] M.A. George, P. Morse, J. Morris, H. Chandra and J. Madocks, "Deposition of Silicon Oxide, Silicon Nitride and Silicon Carbide Thin Films by New Plasma Enhanced Chemical Vapor Deposition Source Technology", Conference Proceedings of the Assoication of Industrial Metallizers, Coaters and Laminators (AIMCAL), 2007.

3:20pm **TF-ThA5 Low Damage Sputter-Deposition System for the Deposition of TCO Films on Organic Films**, *H. Lei, K. Ichikawa, T. Uchida,* ***Y. Hoshi***, Tokyo Polytechnic University, Japan

We examined damages produced in organic materials during sputter-deposition of electrode film by measuring a change of photo-luminescence (PL) intensity of organic light emitting materials and developed a low damage sputter-deposition system. MEH-PPV as polymer and BAlq3 as small molecule were used for the light emitting materials. We compared the damages produced in the deposition of electrode films(ITO) by using different types of sputtering systems, i.e., a facing target sputtering (FTS) system and a conventional planar rf-magnetron sputtering (rf-MS) system. By using FTS system, decrease in PL intensity was suppressed remarkably compared with the using of rf-MS. In addition, removing the bombardment of high energy secondary electrons to the film surface was very effective to reduce the damages of the organic films. Furthermore, reduction of kinetic energy of deposition particles to the organic film surface by increasing sputtering gas pressure was necessary to reduce the damages of the organic films. Finally, we could deposit ITO films on the organic films without damages by using a FTS system, where bombardment of high energy negative oxygen ions, high energy secondary electrons, and high energy deposition particles to the organic film were completely removed.

4:00pm **TF-ThA7 Sputter Deposition of Highly Flexible ITO on Polymeric Substrates**, *M. Yan, A.G. Erlat,* ***B. Scherer***, *P.A. Mcconnelee, A.R. Duggal, T.P. Feist*, GE Global Research

This contribution describes a novel modification to conventional DC magnetron sputtering setup to make highly flexible, conductive and transparent indium tin oxide (ITO) coatings on polymeric films. Such high quality ITO coated polymeric film serves as an ideal substrate for flexible optoelectronic devices such as organic light emitting diodes (OLED), photovoltaics, organic electrochromic devices, and the like. The uniformity and flexibility of ITO coatings on plastic substrates were dramatically improved by inserting a shadow mask between substrate and ITO sputter target and critically positioning the mask to block a spatial region of the sputtering target material from depositing on the substrateIn addition, ITO sputtering process repeatability was improved by preconditioning sputter chamber after cleaning.

4:20pm **TF-ThA8 Thermally Stable Very Thin Ag Films for Electrodes**, ***M. Kawamura***, *D. Fukuda, Y. Inami, Y. Abe, K. Sasaki*, Kitami Institute of Technology, Japan

Low resistivity metals such as Cu or Ag have been paid attention for substituting Al alloy films as gate, source, and drain electrodes in LCD-TFT. Though Ag features with the lowest resistivity among all metals, some serious demerits, e.g. agglomeration by heating, are known. Improvements of thermal stability of Ag thin films have been attempted by especially alloying the Ag films, but it is difficult to preserve its low resistivity due to impurity scattering effect in some cases. We have showed a result of structural modification, where very thin Al oxide layer (about 3 nm of thickness) were introduced at top and bottom of the Ag films (about 95 nm), namely Al/Ag/Al structure. This structure showed excellent stability on surface morphology and electrical resistivity even after annealing at 600^{o}C in vacuum. The resistivity of the film was also as low as that of bulk Ag. Next, reduction of Ag layer thickness down to 50 nm was attempted. The resistivity and morphology of the film were degraded slightly but remarkably superior to those of pure Ag films, and also those of Cu thin films with the same size. Consequently, it is found that the modified Ag films show excellent electrical properties and can be used at elevated temperatures.

4:40pm **TF-ThA9 High Rate Sputtering Deposition of Silicon Oxide Thin Films from New SiO_2:Si Target Composition**, ***Q.H. Fan***, Wintek Electro-Optics Corp, *L.Q. Zhou,* University of Michigan, *D. Stevenson*, Wintek Electro-Optics Corp.

Silicon oxide thin films are widely used in flat panel displays as well as optical and large area architectural type coatings. Two sputtering techniques are commonly used to deposit silicon oxide thin films. For the highest density SiO_2 films RF sputtering using quartz targets is normally preferred.

For large area coating at high rates reactive sputtering using silicon targets and either DC or AC type power supplies is the most common method. RF sputtering results in high quality films but relatively low deposition rates. Reactive sputtering from silicon targets has higher deposition rates but lower film quality. In addition reactive sputtering using planar targets has process stability issues due to target poisoning. The ideal process would combine the high rates of reactive sputtering with the film quality of RF sputtered SiO_2 films from quartz targets. We have successfully developed a conductive SiO_2:Si target (patent pending) that achieves this goal. This target composition can be sputtered using DC, AC or RF power supplies. Using this new target it is possible to reach deposition rates that are at least three times higher than typical RF sputtered SiO_2 films from quartz targets. Further, the SiO_2 film quality that can be achieved is comparable to RF sputtered films from quartz targets. In this paper, we present details of the conductive SiO_2:Si target as well as the resulting SiO_2 film properties and deposition rates that have been achieved. In addition we also provide our preliminary analysis of the deposition process mechanism that enables such high deposition rates and film quality when SiO_2:Si targets are used.

5:00pm **TF-ThA10 Recent Development of Low Temperature Plasma Enhanced CVD of Transparent Conducting Oxide in Photovoltaic Applications**, ***H. Chandra**, M.A. George, S. Higgins, P.L. Morse, J.E. Madocks*, General Plasma Incorporated

Transparent conducting oxide (TCO) is a key component for photovoltaic and display applications. Indium tin oxide (ITO) is the best known TCO material with regard to electrical and optical properties. However, ITO is prohibitively expensive for economical production for these applications. One candidate to replace ITO as TCO material is fluorine-doped tin oxide. It is stable at high temperature, economical to produce and less reactive compared to other TCO materials such as zinc-oxide based TCO[1]. The bulk resistivity of tin oxide films deposited with conventional method (PECVD, spray pyrolysis, atmospheric pressure CVD) is as low as $2x10^{-4}$ Ohm-cm.[1] However, the deposition temperature is typically above 350°C which has limited use for temperature sensitive processes such as quantum dots based solar cells or large area plastic substrates. We have developed a novel PECVD system to deposit tin oxide at lower temperature (below 200°C) while achieving good conductivity. Our tin oxide films have bulk resistivity below $4x10^{-3}$ Ohm-cm at 200°C which is lower than conventionally deposited films at the same process temperature. Furthermore, the linear PECVD source used in this process is scalable to several meter-wide web substrates with film uniformity better than 3%. The deposition rate is typically 200-400 nm-meter/minutes more than an order of magnitude higher than competing sputtering technologies. The scalability to large area with excellent uniformity coupled with high deposition rate is important for economical production of TCO layer. In the present work, we will discuss the PECVD source used in the process, electrical properties (carrier concentration and mobility), optical properties and microstructure of the deposited tin oxide and other TCO thin film materials.

[1]W. Beyer et al., "Transparent conducting oxide films for thin films silicon photovoltaics," Thin Solid Films 516, 147 (2007).

5:20pm **TF-ThA11 Field-Effect Mobility Enhancement of Organic Thin Film Transistors on Flexible Substrates with Organosilanes-based Surface Modification**, *C.G. Takoudis, **L. Jiang***, University of Illinois at Chicago, *J. Zhang, D.R. Gamota*, Motorola

In Organic Thin Film Transistors (OTFTs), the performance is profoundly affected by organic semiconductor crystal formation or organic structure ordering. As it is known, the ability of conjugated molecules to transport charge due to the π-orbital overlap of neighboring molecules provides their semiconducting and conducting properties. The self-assembling or ordering of these molecules enhances this π-orbital overlap and is the key to improvements in carrier mobility. Since the semiconductor materials are deposited on dielectric layer, the surface chemical and mechanical properties of dielectric materials do affect the alignment and the crystal formation of semiconductor. For industrial applications requiring large area coverage, structural flexibility, and low cost, such as printed electronics, each layer is printed on the flexible plastic substrate, so that the dielectric materials have to be printable. In this work, poly(4-vinyl phenol-co-methyl methacrylate) (PVP-PMMA) was used as dielectric cross-linked at 200ºC by mixing with p- Tolyltrimethoxysilane (TTMS) on polyimide substrate, and Aluminum deposited on the polyimide as gate. The carbon ink could be printed on the cross-linked PVP-PMMA to form source and drain. Solution processed bis(triisopropylsilylethynyl) (TIPS) pentacene was deposited either by drop casting or rod coating and the field effect carrier mobility of 10^{-3} ~10^{-5} cm^2/V•s were obtained. The resulting structures and systems were also characterized with differential scanning calorimetry and atomic force microscopy.

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