SYMPOSIUM I
Flexible Electronics—Materials and Device Technology

April 12 - 16, 2004

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* Invited paper
Hydrogenated amorphous silicon (a-Si:H) and nano- or polycrystalline silicon (μc-Si, poly-Si) are the semiconductors used for large-area electronics. They are applied to thin-film solar cells, active matrix liquid crystal displays (AM-LCDs), optical scanners, and radiation imaging arrays. The tutorial describes materials growth and preparation, basic material properties, device physics, and applications. Attention is given to proof-of-the-net, low-temperature processing. Special emphasis will be on the relation between material properties and device performance. Existing and emerging applications will be presented and discussed.

Instructors:
Siegard Wagner, Princeton University
Jaon Pedro Conde, Instituto Superior Tecnico, Lisbon, Portugal

SESSION II: Flexible Electronics
Chairs: Babu Chalamala and Norbert Fruehauf
Tuesday Morning, April 13, 2004
Room 2018 (Moscone West)

8:30 AM *11.1 Strategies for Commercializing Flexible Displays.
Kimberly Allen, iSuppli/Stanford Resources, Santa Clara, California.
Flexible displays are a common suggested application for flexible electronics. These devices have fascinated people for decades, and the first attractive-looking demonstrations have recently become possible. How will the market evolve? At this early stage, the most useful information is of a strategic nature, allowing companies to plan their R&D resources appropriately. This presentation covers technology and manufacturing development, key challenges, favorable applications for flexible displays, and a forecast of the market size through 2010. It includes an examination of LCD, OLEDS, electrophoretic, and other technologies; e-paper, consumer electronics, and other novel products; and potential manufacturing approaches like inkjet printing and standard lithography using batch and roll-to-roll techniques.

Organic light emitting devices (OLEDs) on flexible substrates offer advantages in weight and ruggedness for display applications while also enabling new products such as roll-up displays. For more ambitious applications, such as room lighting, however, the OLED panel will likely be at least a square meter in area and plastic or thin metal foil substrate is a clear necessity if we are to achieve a "organic light" that is not only acceptable but also cheap. Two primary roadblocks are encapsulation of a flexible device and extremely high speed deposition of both the encapsulant and the active organic thin film layers to achieve a price point for the completed device competitive with conventional lighting solutions. We will describe recent advances in flexible barrier coatings and their mode of operation and a new technique of continuous feed, high rate deposition of organic thin film layers which may enable high speed rollcoating of low cost OLEDs on large area substrates.

9:30 AM *11.3 Full Color OLED Displays by Ink Jet Printing. Franky So, Rahil Gupta, Andrew Ingle and Sriram Natarajan; OSRAM Opto Semiconductors, Inc., San Jose, California.
Spin coating is the current process of choice for monochrome polymer OLED displays, but it cannot be used for manufacturing area color or full color displays. Ink jet printing is a promising technique for high resolution area/full color polymer OLED display manufacturing. It offers several advantages over other technologies including high resolution, good control over film thickness, suitability to print on large area substrates, especially flexible substrates, and reduction in costly material usage. In order to use ink jet printing for OLED manufacturing, several key technical challenges need to be resolved and the reliability of the ink jet printing and uniformity of the printed films. For full color OLED display manufacturing, polymer films are printed on to pixilated arrays defined by a bank made with dielectric materials. The surface energies of ITO and the bank materials and their interactions with the optimized polymer inks are the key parameters to control the spreading of the liquid on the substrate. On the other hand ink formulations and their interaction with the print-head control the ink jettability. The formulations and surface properties of the substrate also play a pivotal role in the uniformity of dried films. In this paper, we will first discuss the key parameters to obtain uniform films and show some of our most recent printing results where we have optimized these parameters and obtained uniform polymer films via ink jet printing. The device performance of the printed devices in terms of efficiency and lifetime will be compared with the standard spin coated devices. Finally, we will show our latest results in full color display printing.

10:30 AM *11.4 Low Temperature Poly-Si TFT Technology. Takashi Noguchi, SAI & SKK Unw., Suwon, South Korea.
Low temperature poly-Si TFT technology is reviewed and is discussed from a view point of device, fabrication process and its possibility as a FPD (Flat Panel Display) application. After the appearance of effective crystallizing technique of SPC (Solid Phase Crystallization) or ELC (Excimer Laser Crystallization) using UV (Ultra-Violet) beam, the electronic properties of poly-Si thin-films relating to the high crystallinity of large grain size was improved drastically, and the process temperature for the TFT fabrication was reduced below 600℃ down to 400℃. So far, improvement of device characteristic of poly-Si TFT such as an enhancement of carrier mobility or a reduction of leakage current has been studied intensively for the application to FPD on glass or on stainless steel substrates. Also, extensive study is being gone in order to realize a further functional SOG (System on Glass). By reducing the total process temperature as low as 300℃ or below and by modifying the device structure design, O-LED (Organic LED) FPD addressed by uniform poly-Si TFTs mounted on flexible plastic substrate with high robustness and transparency, such as PES (Poly-Ether-Sulfone) or PET (Poly-Ethylene-Terephthalate) etc is expected. By establishing a reliable low-temperature fabrication process on aryl or flexible substrates by considering their chemical and thermal endurance, the poly-Si TFT has a possibility to develop as a smart SOP (System on Panel) or to rather unique applications beyond the conventional Si LSI in the ubiquitous IT (Information Technology) era.

Nanostructured materials and related technologies for large area, flexible, TFT-based electronics for potential high performance applications will be discussed. While not comparable in performance to conventional devices and circuits, attributes such as distributed (pervasive) electronics, reduced system weight/cost, and flexible form factor allow integration into "smart" objects and building blocks for the development of this technology. While displays, smart cards, and RF tags all benefit from TFT on flexible substrates, existing technology suffers from a significant performance penalty. Specifically, the temperatures required for fabrication of high quality TFTs are incompatible with the flexible substrates of choice. The dominant approach currently is based on either amorphous silicon or organic TFTs, which are expected to provide cost effective manufacturing, but are severely limited in applications that can be addressed because of the low mobility of the devices. To overcome this limitation, a variety of novel materials and/or processes are beginning to be explored. The common element is that the semiconductor material is either processed offline or with in situ flexible heating techniques. The desired result is nanostructured material with properties that rival those of single crystal. Various approaches currently in development will be presented and their progress reviewed. At the extreme, one can envision a future where macroelectronics plays a major role in the electronic systems landscape. While the disparity in performance between existing (and future) Si technology would seem to make this unlikely, the extreme cost pressure being experienced by the worldwide IC industry at least raises the question of alternative approaches. If TFT device performance can improve significantly at the same time the promise of low cost manufacturing can be realized, then perhaps "macroelectronics" can find a role beyond displays.
In recent years, polycrystalline silicon thin-film transistors (poly-Si TFTs) have been extensively investigated for applications in large-area electronics, especially direct application of a standard TFT process to plastic substrates is not in general possible, mostly because of temperature limits and related dimensional stability issues. In addition, standard flat-panel manufacturing processes are not capable of using floppy substrates. Therefore, a new process has to be developed, compatible with a suitable way of handling plastic substrates. Plastic sheets are laminated on glass carrier wafers and run through all the automated tools. A low-temperature process using sequential lateral solidification (SLS) using an excimer laser. Non-thermal melting on transparent a-Si to poly-Si was induced by the intense peak power of infrared ultrashort laser pulses which leads nonlinear photo energy absorption and generation of very dense photoexcited plasma. FLA assisted by sequential lateral solidification constitutes super lateral epitaxy that can crystallize amorphous silicon into polycrystalline silicon with large grains of 1 micrometer, even when a-Si films are irradiated at a ultralow laser fluence of 45 mJ/cm² and low laser-to-surface distance. FLA transfer characteristic shows good device performance, particularly as regards uniformity, as the laser shot number was 100. Electron Backscatter Diffraction Pattern (EBSP) analysis indicated that <111>-oriented Si grains of a-Si:H vertical thin film transistor (VTFT) are achieved only in the convex region but also around it. The size of the grains, can be realized at this low temperature site. The essentially GBs are thought to be electrically inactive, unlike random GBs, and avoid GBs in the TFT channel. We propose a novel approach to form position-controlled Si grains by using a-Si precursor film having convex regions of several μm. In this way, high-performance TFTs are achieved. A 47-nm-thick a-Si layer was deposited on a glass substrate. A part of the layer was etched by plasma etching to form a square convex region with sides ranging from 2μm to 12μm. The etching depth was about 7nm. This is because the thicker convex region has a larger heat capacity than the adjacent thinner region. Preferential nucleation, that is control of the location of grains, can be realized at this low temperature site. The essentially <111>-oriented Si grains of a-Si:H vertical thin film transistor (VTFT) are a promising crystallization method. However, the performance of poly-Si VTFTs formed using conventional ELA is limited; the resulting small grain size is not only the problem for the positional difference between the heating and cooling rate of a-Si inside the pattern, and finally the grain boundary is completely formed not only in the convex region but also around it. The size of the essentially round-shaped grains was several μm. Practically only <111>-oriented grains were observed in the <111>-oriented grains. Recently, we have developed a new process for the crystallization of a-Si:H thin film transistors (VTFTs) with critical dimensions of 100nm, by improving the performance of ELA to increase the maximum process temperature for high performance TFTs. Two annealing steps are adapted in the fabrication process of TFT device: one is channel-region annealing and the other is post-implantation annealing. Active region composed of amorphous silicon (a-Si) was crystallized by femto-second laser annealing (FLA) using a laser with Ti:sapphire laser. Solutions to these challenges are discussed and TFT transfer characteristics on glass and plastic substrates are presented. Finally, images from prototypes of monochrome AMOLED displays are presented, with 64x64 pixels and 80 dpi resolution.
3:30 PM *12.5/A3.5
Issues in processing a-Si/nc-Si TFTs on flexible substrates.
Sigurd Wagner, Electrical Engineering, Princeton University, Princeton, New Jersey.

Long ago silicon migrated long ago to unconventional substrates. Amorphous silicon is stable under a great variety of conditions. A-Si thin film transistors are made on glass. The tremendous technology base of silicon stimulates continued experimentation with silicon on unconventional substrates. Fascinating results can be obtained that way. Many macroscopic concepts rely on flexible, shaped, or even elastic electronic surfaces. Integrating Si TFTs with the appropriate substrates raises many process issues. They stem largely from the fact that flexible substrates are so different from crystalline silicon and glass, for which the integrated circuit processes have been developed. The physical properties of the substrate define many process conditions. Future important is the maximum process temperature, which imposes the selection of suitable materials and design processes. Techniques for substrate passivation, planarization, and film adhesion also directly flow from the choice of substrate. Often these functions are coupled. The choice is critical to the building of a thin film structure on a flexible substrate. Dimensional instability and differential thermal expansion likewise shape process conditions. Shrinking and warping calls for pre-process bake. Layers must be made to adhere strongly to the substrate but also cause no thermal contraction. Electronics that just need to flex can be made on substrates that remain fully coated with a passivating layer during the entire fabrication process. The process steps this layer makes the substrate material look like the passivating material. Fortunately SiNx and SiO2 work well as adhesion and passivating layers, and allow using standard silicon fabrication processes. Electronic surfaces that can be shaped or deformed reversibly pose a much bigger problem. Many fabrication techniques for the TFT substrate must be exposed, which means that the passivation layer must be stripped. Because the properties of the substrate can be vastly different from those of silicon TFT materials, from that point on control processes, patterning techniques and materialization procedures must be employed. In the following I will illustrate these processing issues with specific examples.

3:30 PM *12.6/A3.6
Flexible Electronics Devices using SUFTLA and Micro Liquid Process.
Tatsuya Shimoda, Technology Platform Research Center, Seiko Epson Corporation, Suwa-gun, Nagano-ken, Japan.

For fabrication of flexible electronics devices, SUFTLA technology and a micro liquid process, in which an inkjet printing is included, are very promising. We have already developed several devices using these technology in Seiko Epson Corporation. They not only enable us to fabricate flexible devices but also give us a versatile means for a flexible production system. SUFTLA, which stands for "Surface Fee Technology by Laser Annealing/ablation", is a technology that enables TFTs and TEF devices to be transferred from the original substrate to any substrate by using the laser to melt the material. A small droplet of liquid is also spread on the substrate and it is evaporated. The properties of the substrate can be vastly different from those of silicon TFT materials, from that point on control processes, patterning techniques and materialization procedures must be employed. In the following I will illustrate these processing issues with specific examples.

4:00 PM *12.7/A3.7
Temperature Dependent Carrier Transport in Single Crystalline Si TFTs inside a Location-Controlled Grain.
Vilain Rana, Ryochi Ishihara, and C.M. Beenakker; ECTM/DIMES, Delft University of Technology, Delft, Delft, zuid-holland, Netherlands.

Precise location-control of a grain in excimer-laser crystallization process allows us to eliminate the grain boundaries from active area of thin film transistor, i.e. single-crystalline Si TFTs (c-Si) TFTs. TFTs fabricated inside a location-controlled grain by µ-Czochralski process [1] showed an high field effect mobility of 450 cm2/Vs and low-leakage current of 10−13 A. [2] The high performance of c-Si TFTs will allow us to design system circuits as well as driver circuits with display, i.e., system on glass. In present work, to understand mechanism of carrier transport of the c-Si TFTs in detail, the temperature dependences of I-V characteristics of c-Si TFTs fabricated inside a location-controlled grain by µ-Czochralski (µ-Cz) (grain-filter) process were studied. The n-channel TFTs used in this study were fabricated with µ-Czochralski process [1] as follows. A grid of cavity (grain-filter) (size 100 nm) was made in SiO2 by photolithography. Subsequently, a 300 nm thick a-Si was deposited by LPCVD using silane at 545°C and fills the grain-filter. The samples heated at 450°C were crystallized with XeCl excimer-laser with various energy densities. TFTs having W/L of 3.2/1.28/6.8 μm, were fabricated inside a grain with top gate, self-align structure having LPCVD SiO2 (120 nm) as a gate insulator. N-type Si substrate. Temperature dependence of carrier mobilities was measured. Temperature dependence of I-V characteristics of TFTs were measured for gate voltage Vgs ranging from -10 to 10 V at a drain voltage of 0.2 V. Activation energies for were calculated from an Arrhenius plot by means of current obtained at Vgs = 12.9, 17.9, 22.9, 27.9, and 32.9 V. At ON-state (Vgs = 10 V), the Ea drops to negative value (−0.01 eV), which is distinct from a typical poly-Si TFT. The value indicates that bulk trap states density is very low and TFT behaves like single-crystalline MOSFETs. This was varied for a wide range of laser energy densities. With a low laser energy density, the Ea value at OFF-state (Vgs = −10 V) is calculated to be 0.52 eV, which indicates that the leakage current is thermally activated at mid-gap states. In contrast, for a high laser energy density, the Ea value at OFF-state (Vgs = −10 V) was nearly constant at 0.7 eV. This suggests that the defect creating mid-gap states, e.g., random grain boundaries, were diminished, as a result of the high laser energy density and hence a long melt duration. Leakage current is dominated rather by trap states located in the band tail, which may be caused by remaining coherent grain boundaries in the location-controlled grain. [1] P.C. van der Wilt, B.D. van Dijk, G.J. Bertens, R. Ishihara, and C.M. Beenakker, fabrication of location crystalline islands using substrate embedded seeds in excimer-laser crystalization silicon film, Appl. Phys. Lett. 79, 1819 (2001). [2] R.Ishihara, P.C. van der Wilt, B.D. van Dijk, J.W. Metselaar, and C.M. Beenakker, Properties of single crystalline Si TFT fabricated by µ-Czochralski (grain-filter) process, Proc. of SPIE, Vol. 5004 (2003) Pg.10-19

4:15 PM 12.8/A3.8
Elastic integrated circuits on elastomeric skin.
Stephanie Perichon Lacour and Sigurd Wagner; Electrical Engineering, Princeton University, Princeton, New Jersey.

Elastic integrated circuits are essential for robotic sensor skin that can stretch, wrinkle or shrink while transmitting data to embedded sensors. In this paper, we demonstrate the first stretchable integrated circuits made of thin film transistors (TFTs) on elastomeric membranes, and interconnected with stretchable gold conductors. We begin by fabricating stretchable contact pads using SUFTLA technology, interconnecting stretchable gold conductors. We then fabricate amorphous silicon thin film transistors, fabricated on plastic foil with the gold conductors on the elastomer membrane to form active load inverter circuits. We describe the complete fabrication process, including the application of novel electrical contacts on elastomeric substrates. We also present the electrical performance of the inverter circuits prior to, during, and after 3D mechanical stretching.

3:40 PM *12.9/A3.9
Reel-to-Reel Cassette Cluster Tool System with PECVD and Pulsed PECVD Deposition Techniques.
Arum Madan, MVSystems Inc., 80401, Colorado.

Cluster tool (or multi-chamber) systems are generally used in the production of amorphous silicon thin film transistors, solar cells, etc.
In this, each process chamber (e.g. PECVD for SiNx, intrinsic and doped amorphous silicon, sputter deposition techniques for metallization and ITO) is physically separated from others via gate valves in order to avoid cross contamination, which is crucial in obtaining optimal performance of an electronic device. The planar substrate is transported via a robotic arm from one chamber to another. Flexible amorphous silicon p-i-n type solar cells are produced using a roll to roll approach. In this, a large roll of material (e.g. a mile long) is transported through the various process zones; an attempt is made to minimize the cross contamination, between the doping and interconnect process regions, via the inclusion of slits, gas curtains, differential pumping etc. As is inevitable, cross contamination of the intrinsic layer due to Phosphorous and Boron persists thus preventing an optimal performance of the resulting device. We present a new type of system architecture (1) to fabricate thin film silicon devices, such as TFT’s on to flexible substrates, which uses the inherent advantages of the cluster tool. In this, a large quantity of the flexible substrate material is contained within a cassette which can be changed to a new wafer. As in the current cluster tools for planar substrates, the cassette is transported to a process chamber using a robotic arm; within the process zone (e.g. SiNx using the PECVD technique), the cassette is engaged to motors to move the flexible material in a reel-to-reel operation. When the entire roll in the cassette has been processed, it is disengaged from the motors and transported into other chambers for further processing (e.g. intrinsic or doped amorphous silicon, sputter deposition of metals, or ITO). We also discuss the use of the pulsed PECVD deposition technique, which allows an increase in the electron density during the ‘ON’ cycle, thus allowing the deposition rate of amorphous silicon to exceed 15 A/s. In the ‘OFF’ cycle, the ions responsible for dust formation in the process zone are neutralized. We show that high quality micro- (or nano) crystalline Silicon can be produced using a modified pulsed PECVD technique. In particular, at a deposition temperature as low as 200 °C, materials result with a grain size of 200 Å, low O concentration and a minority carrier diffusion length of more than 10 μm. The thickness of the active layer is therefore limited in terms of mobility and stability of operation, innovative threshold-voltage-shift-compensated pixel circuits [1,2] are making it possible to construct active matrix OLED prototypes with a-Si TFT processes optimized for device performance. In addition, there has been a dramatic progress in efficiency of OLED materials over past few years [3] enabling lower drive current requirements, which relaxes the constraints on n-Si TFTs. Making the a-Si TFT process compatible to plastic substrates requires a reduction of process temperature from 300 celsius to 150 celsius or below, which tends to compromise the quality of thin-film materials and device performance. Hence, optimizing the TFT process for high device performance with limited thermal budget is a necessary step towards flexible AM-OLEDs with a-Si backplanes. We have developed and extensively characterized low temperature a-Si TFT processes for plastic substrates [4]. Our TFTs on plastic substrate have effective mobility of 0.8 cm2/Vs, threshold voltage of 4 V, subthreshold slope of 0.5 V/decade and pA leakage current that is similar to good quality devices on glass fabricated at higher temperatures. Highly stable threshold-voltage-shift-compensated a-Si TFT pixel driver circuits have been fabricated on the plastic substrate. The performance of pixel circuits is examined in terms of current driving ability, linearity, dynamic range and transient response, and more importantly, long term stability. Initial tests of circuit degradation behaviour over extended time periods and stable device currents. We will present the long-term circuit stability of our circuits along with a systematic comparison of stability and lifetime of voltage- and current-programmed circuits. [1] A. Nathan, D. Striakhilev, P.

SESSION 13: Flexible Si TFT Circuits
Chair: Jin Jang
Wednesday Morning, April 14, 2004
Room 2018 (Moscone West)

Amorphous silicon (a-Si) technology is an attractive candidate for active-matrix OLED displays because of its maturity and low-cost. Even though amorphous silicon transistors (TFTs) are somewhat limited in terms of mobility and stability of operation, innovative threshold-voltage-shift-compensated pixel circuits [1,2] are making it possible to construct active matrix OLED prototypes with a-Si TFT processes optimized for device performance. In addition, there has been a dramatic progress in efficiency of OLED materials over past few years [3] enabling lower drive current requirements, which relaxes the constraints on n-Si TFTs. Making the a-Si TFT process compatible to plastic substrates requires a reduction of process temperature from 300 celsius to 150 celsius or below, which tends to compromise the quality of thin-film materials and device performance. Hence, optimizing the TFT process for high device performance with limited thermal budget is a necessary step towards flexible AM-OLEDs with a-Si backplanes. We have developed and extensively characterized low temperature a-Si TFT processes for plastic substrates [4]. Our TFTs on plastic substrate have effective mobility of 0.8 cm2/Vs, threshold voltage of 4 V, subthreshold slope of 0.5 V/decade and pA leakage current that is similar to good quality devices on glass fabricated at higher temperatures. Highly stable threshold-voltage-shift-compensated a-Si TFT pixel driver circuits have been fabricated on the plastic substrate. The performance of pixel circuits is examined in terms of current driving ability, linearity, dynamic range and transient response, and more importantly, long term stability. Initial tests of circuit degradation behaviour over extended time periods and stable device currents. We will present the long-term circuit stability of our circuits along with a systematic comparison of stability and lifetime of voltage- and current-programmed circuits. [1] A. Nathan, D. Striakhilev, P.

SESSION 14: Organic TFTs I
Chair: Norbert Fuchs
Wednesday Morning, April 14, 2004
Room 2018 (Moscone West)

Organic thin-film transistors (OTFTs) have been rapidly developed in the past few years. Especially, pentacene TFT has a field effect mobility of higher than 0.1 cm2/Vs. Therefore, OTFTs have many applications requiring large-area coverage, structural flexibility and low cost. However, there are many issues in TFT process. One problem in fabricating organic transistor is difficult in patterning the
organic active layer using photolithography. While bulk pentacene is relatively insoluble and non-reactive in the typical solvents used in photolithography, the performance of pentacene TFT is dramatically degraded by exposure to solvents. In this work, we made an active island without using photolithography. Note that the conventional photolithography cannot be used for OFETs. The source-drain contacts of pentacene TFTs can be made by annealing of two structures-top (inverted staggered) and bottom contacts (inverted coplanar). The bottom contact structure gives inferior performance to the top contact. By this reason, the top contact structure is widely studied. Shallow etching technique for the back-channel growth and drain on pentacene film for TFT fabrication, but this is not a suitable structure for display manufacturing. Since no photolithography process can be performed after pentacene is deposited, bottom contact device is the only option for high-resolution displays. Therefore, we studied a bottom contact structure. We have studied bottom-gate organic thin-film transistors with a selectively grown pentacene on plastic structure. The pentacene can be self-organized in the OTFT process. An organic vapor phase deposition is very effective to have the active islands for display manufacturing. By using this self-organized technology, the organic thin-film transistors with a field-effect mobility of 0.41 cm2/Vs, a threshold voltage of +1 V, an IL/IF ratio of 104 and off-current of less than 10 pA/μm have been demonstrated.


A major goal of organic transistor development is to minimize the limitations in performance caused by grain boundaries, both in bulk-sublimed and in solution-deposited films. Here we present data from devices prepared by the direct application of macroscopic single crystals to polymer dielectrics, discussing the insights gained from their examination as well as nonidealities in the experiments. We then study the mechanism of deposition of semiconductor oligomer films from solution that also results in devices comprising macroscopic crystallites. Much higher mobilities are observed from these devices than previously observed from solution deposited to solid films. The role of mesophasic, interfacial effects, and annealing in the deposition is discussed.

11:00 AM 14.3 Stability of Organic Thin Film Transistors. Jeong-In Han, Yong-Hoon Kim, Sung-Kyu Park, Dae-Gyu Moon and Won-Keun Kim; Information Display Research Center, Korea Electronics Technology Institute, Puyang-ri, Kyunggi, South Korea.

Recently, the stability of organic thin-film transistors has become one of the most important issues in thin are of research. In this report, we investigated the stability of poly (3-hexylthiophene) (P3HT) field effect transistors (TFETs), discussing the insights gained from their examination as well as nonidealities in the experiments. We then study the mechanism of deposition of semiconductor oligomer films from solution that also results in devices comprising macroscopic crystallites. Much higher mobilities are observed from these devices than previously observed from solution deposited to solid films. The role of mesophasic, interfacial effects, and annealing in the deposition is discussed.

11:30 AM 14.4 Two origins of source/drain series resistance in bottom-contact pentacene thin-film transistors. Makoto Noda, Nobuhito Yoneya, Nobukazu Hirai, Kazumasa Nomoto, Masaru Wada and Jiro Kashihara; Sony Corporation, Osaka, Japan.

Two different origins of the source/drain (S/D) series resistance (Rs) were found in bottom-contact (BC) pentacene thin-film transistors (TFETs): first, the mixed phase of pentacene grown in the blurred edge region of Au electrodes and second, the semi-insulating region in a pentacene layer between Au and a carrier accumulating layer. It is known that the electric characteristics of organic TFTs with a short gate length are affected by Rs [Nechudov et al. Solid-State Electronics 47, 250 (2003)]. Recently, we measured the typical structure of the BC TFET. In the BC TFET, bottom contact devices were measured in vacuum, dry N2 and air environment as well as nonidealities in the experiments. We then study the mechanism of deposition of semiconductor oligomer films from solution that also results in devices comprising macroscopic crystallites. Much higher mobilities are observed from these devices than previously observed from solution deposited to solid films. The role of mesophasic, interfacial effects, and annealing in the deposition is discussed.

12:00 PM 14.5 Temperature-Dependent Contact Resistance in High Quality Polymer Field Effect Transistors. Douglas Nataf 1,2 and Byung J. Hamachan 1; 1Physics and Astronomy, Rice University, Houston, Texas, 2Electrical and Computer Engineering, Rice University, Houston, Texas.

We report measurements of the parasitic contact resistance and the true channel resistance in bottom contact poly(3-hexylthiophene) (P3HT) field effect transistors with channel lengths from 400 nm up to 40 μm, from room temperature down to 77 K. For fixed gate voltage, the ratio of contact to channel resistance decreases with decreasing temperature. We find that the contact resistivity is approximately inversely proportional to the field-effect mobility over 4 decades of mobility. We compare these results with a recent model for metal-organic semiconductor contacts. Mobilities corrected for this contact resistance approach a record 1 cm2/Vs at room temperature and high gate voltages.

SESSION 15: Organic TFTs II

Chair: Bruce Gnade

Wednesday Afternoon, April 14, 2004
Room 308 (McCue West)

1:30 PM 15.1 Short-channel polymer field-effect transistors with self-assembled thin polymer dielectrics. Lay-Lay Chen, Peter K. Ho, Richard H. Friend and Henning Sirringhaus; Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom.

Polymer field-effect transistors (FETs) manufactured by solution processing and direct printing are one of the most promising approaches for integrating electronic functionalities onto flexible plastic substrates. Downsizing of channel length is one of the paths for improvement of their device performance. It is also reported that with the help of surface energy patterning of the substrate inkjet printing is capable of defining submicrometer critical feature sizes enabling fabrication of polymer FETs. However, in order to realize high mobilities, submicron channel dimensions, in particular the gate dielectric thickness need to be scaled down to thicknesses much less than 100 nm. This is difficult to achieve with conventional polymer dielectrics posing problems with pinhole formation and increased leakage current when the thickness is dropped below typically 150 nm. In the present work we present several novel approaches to fabrication of high performance polymer dielectrics with thicknesses down to 10 nm. In one approach a self-assembled bilayer is formed from a ternary blend solution containing both the dielectric and the semiconducting polymer, or precursors thereof. This method enables formation of ultrathin, thermodynamically stable dielectric layers. Through kinetic control of the structural properties of the polymer-polymer interface, the method allows for fine-tuning the systematic study of the dependence of the field-effect mobility on the surface roughness at a polymer-polymer interface. We will also discuss the effects of dielectric purity on device performance and stability.
1:45 PM | 15.2 Organic transistor based thin-film electronics, Ananth Dodabalapur, 1 ECE, UT-Austin, Austin, Texas; 2ECE, UT-Austin, Austin, Texas.

This talk will review progress in realizing devices, circuits, and systems based on organic and polymer semiconductor based thin-film transistors. Such devices have been used to make large-scale circuits, display systems, chemical and biological sensors, and identification tags. However, there are challenges, such as optimum gate dielectric as well as fabrication processes that are suitable for low-cost manufacturing. The performance characteristics of organic FETs places constraints on circuit speeds, but this is compensated for by ease of production. This trade-off, as well as some unique properties such as chemical sensitivity, will influence the use of such transistors in commercial applications.

2:15 PM | 15.3 Four-probe electrical measurement on a dry-etched pentacene OTFT, Iwao Yagi 1, Kazuhiro Tsunogoshi 1,2 and Yoshinobu Aoyagi 1, 1RIKEN, Saitama, Japan; 2PRESTO, JST, Saitama, Japan.

In organic thin-film transistor (OTFT), the interface at the channel/electrode could have a crucial influence on the device performance. Actually, large contact resistance was pointed out even in pentacene OTFT, which exhibited higher field-effect mobility among the OTFTs, from the analysis of the result of two-probe electrical measurement. To directly observe the effect of contact resistance, the total resistance should be divided into the contact resistance component and the channel resistance, thus a four-probe electrical measurement of the pentacene OTFT device is required. To fabricate precisely patterned pentacene OTFT device for a four-probe electrical measurement, we proposed and developed a new dry-etching method for the pentacene thin-film. In this method, pulsed Nd:YAG laser irradiation at the wavelength of 355 nm was used to remove away the pentacene thin-film in the irradiated area. The sample for the four-probe measurement was fabricated with applying the etching process to the channel of a prefabricated pentacene OTFT on SiO2/Si substrate with multiple top contacts. The results of the four-probe measurements revealed that both the channel resistance and the contact resistance changed with applied gate voltage. When the gate voltage (Vg) of -80 V was applied, the contact resistance reduced to be smaller than 1 % of the value at Vg = 0 V, while the channel resistance reduced to about 10 %. This suggests that this large gate-dependent change in the contact resistance is dominant in the operation of the pentacene OTFT. In our presentation, we would like to present the details of the patterning processes and the experimental results in the four-probe electrical measurements of the pentacene OTFT devices.

2:30 PM | 15.4 Short Channel Effects in Regioregular Poly(thiophene) Thin Film Transistors, Michael L. Chabinyc, Jeng-Ping Lu, Alberto Salleo and Robert Street, Palo Alto Research Center, Palo Alto, California.

Semiconducting polymers are being considered as a replacement for amorphous silicon in thin film transistors (TFTs) in display backplanes. Understanding the electrical characteristics of polymeric TFTs is essential in the design of display backplanes. We have investigated the performance of polymeric TFTs with channel lengths from 5 to 50 μm fabricated with a regioregular poly(thiophene), P3HT. We observed a pronounced dependence of the output current, bias stress and sub-threshold slope on channel length. The saturated mobility of P3HT-based TFTs can be as high as 0.7 cm2/Vs with high drain voltages when extracted from transfer characteristics in short channel devices. This mobility would represent record performance for a polymer semiconductor, however, examination of the full characteristics of the TFTs shows that the high currents are, in fact, due to short channel effects. Measurements of space-charge limited currents support this interpretation. The implications of these results for material characterization and for the design of polymeric TFTs for display backplanes will be discussed.

2:45 PM | 15.5 All-organic printable logic circuits on paper-substrates, David Nilsson 1, Robert Forchheimer 2 and Magnus Berggren 1, 1Dept. of Science and Technology, Linköping University, Norrköping, Sweden; 2Dept. of Electrical Engineering, Linköping University, Linköping, Sweden.

We report logic circuits based on electrochemical transistors printed on paper-like substrates. Simple electronic elements such as inverters and oscillators have been extended and combined into larger logical systems. The transistor is based on the popular conducting polymer, poly(3,4-ethylenedioxythiophene) (PEDOT) doped with poly(styrene sulfonic acid) (PSS). By changing the oxidation state of the PEDOT:PSS within the transistor it is possible to modulate the current level, resulting in devices with operating voltage below 3V that require no critical dimensions (typical channel width is around 500 microns). Only organic materials are used to manufacture the devices; the electrolyte can either be liquid or gelled, both cellulose based paper and polyester foil can be used as the substrate. Together with common printing techniques this results in environmental friendly and inexpensive circuits.

3:30 PM | 15.6 Organic Light Emitting Diode (OLED) - Technology Convergence, Stewart Edword Hough, AFA, Madera, California.

Organic Light Emitting Diode (OLED) technology has been the focus of intense development by literally hundreds of companies, universities and other organizations over the last decade. Application of OLED technology has most notably been applied to electronic displays, but the technology also has potential in the lighting and photovoltaic industries. The potential performance and cost advantages of OLED displays offer many to consider them as a disruptive technology that could eventually replace CRTs and even LCDs. A number of diverse and even disparate technologies are converging in the OLED platform and have either been adapted for OLEDs from existing technology bases or are nascent and in various stages of development. Ourease of the term potential is deliberate and appropriate in discussing OLEDs as no flat panel (FPD) display technology invented or developed to date has the overall feature set - visual appeal, mechanical form factor, or lower cost manufacturing options - that OLEDs ostensibly offer. This advantage is currently undervalued: over a decade of development and yield improvements, the emergence of first generation manufactured displays - mostly single color alphanumeric, with a single full-color OLED. This is actually an accomplishment of note as newly invented display technologies often take decades or more of research and development to get to first commercial implementation. The early pace of development and considerable over-promotion produced unrealistic expectations for the technology's early commercial success, but with the positive result that the industry is now focused on the remaining challenges to secure first level market opportunities. Understanding and modeling the risk factors associated with the technology elements that have converged to constitute an OLED display can provide helpful insight and perspective to the development challenges the industry will face with future technology discoveries.

4:00 PM | 15.7 Electronic transport of pentacene Thin Film Transistors using organic gate dielectrics, Dietmar Knipp 1,2, Robert A. Street 3, Armin R. Volker 2 and Pravesh Kumar 4; 1Science and Engineering, International University Bremen, Bremen, Germany; 2Electronic Materials Laboratory, Palo Alto Research Center, Palo Alto, California.

The electronic transport of pentacene thin film transistors (TFTs) on organic dielectrics were investigated. Organic dielectrics facilitate the fabrication of low cost electronics on flexible substrates. Organic dielectrics offer promise in the performance of the gate dielectric on the morphology of the pentacene films and the device performance of the TFTs were studied. The poly crystalline films were prepared by thermal evaporation on top of benzocyclobutene (BCB) and poly(methylmethacrylate) (PMMA) gate dielectrics. Careful control of the preparation conditions of the dielectric and the pentacene films lead to TFTs with mobilities of 0.4 cm2/Vs on different organic dielectrics. Therefore, the mobility is comparable with the mobilities observed for inorganic dielectrics like thermal oxide and plasma enhanced chemical vapor deposited silicon nitride. The subthreshold slope increase of TFTs on PMMA is improved by a factor of 2.3 comparing the slope with the best results obtained for inorganic dielectrics (considering the thickness and the dielectric constant of the dielectric). Subthreshold slopes of 0.4V/decade were measured for 200nm thick PVP films. Furthermore, the TFTs on PMMA exhibit threshold voltages very close to 0V. The results reveal that the pentacene molecules tend to arrange themselves on anisotropic surfaces than on the inorganic surfaces, which might lead to better structural order within the first monolayers. The influence of the organic dielectric on the device performance and the electronic transport will be discussed.


We present the use of polymeric aperture masks in fabricating high performance pentacene-based integrated circuits patterned over areas as large as 15cm x 15cm on biaxially stretched polymeric substrates. Devices over the entire patterned areas were functional, and...
performance statistics will be included. Devices consisted of shadow-mask patterned layers of gold, aluminia and pentacene. TFT mobilities greater than 1 cm²/Vs were measured and propagation delays from 7-stage ring oscillators of less than 5 microseconds were observed. This all-additive, dry patterning method has been extended to the production of all-patterning devices using aluminum for the electrodes, silicon dioxide for the dielectric and ZEO as the semiconductor. Larger aperture masks are under investigation and continuing efforts include application to display backplanes, automation of the alignment process, and lifetime and bias stress profiles of devices fabricated on large substrates.

4:30 PM 15.9
Organic field-effect transistors with bending radius down to 1 mm
Tsuyoshi Sekitani1, Hiroshi Kawaguchi2, Takayasu Sakurai1 and Taka Soneya1; 1Quantum-Phase Electronics Center, The University of Tokyo, Tokyo, Japan; 2Center of Collaborative Research, The University of Tokyo, Meguro-ku, Tokyo, Japan.

We have investigated the allowed bending radius of high-quality pentacene organic field-effect transistors (OFETs) manufactured on a plastic substrate, and found that the reduction of mobility due to the application of a bending stress with a radius of curvature (R) smaller than about 3 mm, was only 20%. This remained true even at R = 1 mm. We also studied the recovery performance after stressing OFETs. High-performance OFETs with a mobility of 0.3 cm²/Vs and an on/off current ratio of above 10⁵ have been fabricated by a vacuum evaporation process. The OFETs were used for full temperature and vacuum evaporation of 5 nm Cr and 50 nm Au through a shadow mask on a 75 µm flexible polyimide sheet plastic substrate. Then, a polyimide gate dielectric layer was prepared by spin coating and a 30 nm thick pentacene film has been deposited through a shadow mask. Finally, the 50 nm Au drain-source electrodes were formed using a shadow mask. The channel length and width of OFETs are normally 50 µm and 16 µm, respectively. The electrical properties of the OFETs were measured using a three-lead probe (Agilent Technologies 4156C: Precision Semiconductor-Parameter Analyzer) while the OFETs were stressed using a stress apparatus. The apparatus consists of a cylinder of radius R variable from 50 to 1 mm, corresponding to an expansive force F = 10⁸ N/m² on the substrate. The bending stress is essential to enhance the crystallization of amorphous Ge or GeSi films at reduced temperatures. Annealing of these samples takes more than 12 hours. The crystalline quality of the films has been verified using SEM, TEM, Raman spectroscopy and XRD. The amount of crystalline Ge films has been used to fabricate thin film transistors on PET substrates. The crystalline Ge films have been used to fabricate thin film transistors on PET substrates.

4:45 PM 15.10
Comparison between organic transistors: effects of material properties and device geometry
Omeda Sano1, Yasuhiro Ikeda2, Akihiko Toda1, Takehiko Sakurai1, Minoru Nishiyama1, Hiroshi Hori1, Hiroshi Miyauchi2, Hiroshi Kawaguchi2, Takeshi Itoh2
1Department of Electrical and Computer Engineering, University of Toronto; 2Materials Science Centre, Institute of Scientific and Industrial Research, Osaka University.

Two identical structures of Pentacene thin film transistors have been investigated that differ only for the type of insulator layer on which pentacene has been deposited during the same thermal evaporation process. One is made on a heavily doped silicon substrate with a silicon dioxide insulating layer, the other was made with an identical geometry, on a fully flexible insulating film that acts also as the mechanical support of the whole structure. The relevant differences observed in the electrical characteristics (both static and dynamic) demonstrate that the substrate has a strong role in determining the mobility of the semiconductor. The recorded mobility is significantly different and AFM images were obtained, that confirm the role of grain size and orientation on the recorded mobility of pentacene. - the parasitic capacitance effects due to the superposition (e.g. due to superposition) strongly influence the dynamic behaviour observed in electrical characteristics. The true role of the organic semiconductor in determining the dynamic parameters of the device can be only observed if the structure is free of such capacitance effects.

SESSION 16: Poster Session: Flexible Materials and Device Technology I
Chair: Bruce Grade

Wednesday Evening, April 14, 2004
8:00 PM
Salons 8-9 (Marriott)

16.1 High-Performance Nanowire Electronics and Photonics on Glass and Plastic Substrates
Robin Sean Freeman1, Mike C. McAlpine1 and Charles M. Lieber2

The merger of nanoscale building blocks with flexible and/or low cost substrates could enable the development of high-performance electronic and photonic devices with the potential to impact a broad spectrum of applications. We demonstrate that high-quality, single-crystal nanowires can be assembled into inexpensive, lightweight, flexible plastic substrates to create basic transistor and light-emitting diode devices. In our approach, the high-temperature synthesis of single-crystal nanowires is separated from ambient-temperature solution-based assembly to enable the fabrication of single-crystal-like devices on virtually any substrate. Silicon nanowire field-effect transistors were assembled on glass and plastic substrates and display device parameters rivaling those of state-of-the-art amorphous silicon and organic transistors currently used for flexible electronics on plastic substrates. Nanowire transistor devices have been configured as low-threshold logic elements with gain; moreover, the high-performance characteristics are relatively unaffected by changes in the number of vertices per nanowire or by repeated bending. The generality of this approach is further illustrated with the assembly of gallium nitride nanowire UV-light-emitting diodes on flexible plastic substrates. These results suggest that nanowires serve as high-performance evaporation masks, opening blocks for the next generation lightweight display, mobile computing, and information storage applications.

16.2 Poly germanium and germanium-silicon alloys on plastic for realization of thin film transistors
Bahman Hekmatshoar1, Davood Shahgholi1, Shams Mohajerzadeh1, Ali Khakifirooz2 and Michael Robertson2
1Electrical and Computer Engineering, University of Tehran, Tehran, Iran; 2Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Boston, Massachusetts; 3Physics, Acadia University, Wolfville, Nova Scotia, Canada.

Stress-assisted crystallization of amorphous germanium and germanium-silicon alloys on plastic substrates is reported. PET and Kapton plastic bases have been used to deposit Ge and Si-Ge thin films, and to fabricate depletion and enhancement mode transistors. The Ge sample consists of consecutive layers of GeSi, Cu-Ge and the top GeSi films. The Cu-Ge layer is the seed of crystallization of the top and bottom SiGe layers. For the Ge sample, the SiGe layer is replaced with pure germanium. After cleaning the plastic substrate in a plasma reactor, they are given a step of RCA1 solution followed by blow-drying. All depositions are carried out in vacuum with a base pressure of 1×10⁻⁶ Torr and by e-beam evaporation. Thermally-activated co-evaporation of Ge. Various constituents of the Ge-Si sample have thicknesses of 300, 100 and 100Å, respectively. Crystalization of Ge or Si-Ge layer is achieved using an external compressive stress during annealing at temperatures ranging from 150°C to 180°C. The amount of external mechanical stress is set at 0.05%. This external mechanical stress is essential to enhance the crystallization of amorphous Ge or SiGe films at reduced temperatures. Annealing of these samples takes more than 12 hours. The crystalline quality of the films has been verified using SEM, TEM, Raman spectroscopy and XRD. The percentage of Ge in Ge-Si alloy has been examined using RBS and was found to be 30-50% for different samples. Based on cross-sectional TEM, the Cu-Ge layer acts as the seed of crystallization for the rest of Ge-Si alloy and the growth progresses, epitaxially, from the seed layer onto the Ge-Si film. TEM study of the films suggests that some grains become dominant and epitaxial growth from top to bottom is observed. Based on our investigation, PET seems to be more suitable due to its inherent stress. It is also a transparent and inexpensive substrate. The crystalline Ge films have been used to fabricate thin film transistors on PET substrates. The sheet resistance of such layers has been monitored during the thermal evaporation process. One is made on a heavily doped silicon substrate with a silicon dioxide insulating layer, the other was made with an identical geometry, on a fully flexible insulating film that acts also as the mechanical support of the whole structure. The relevant differences observed in the electrical characteristics (both static and dynamic) demonstrate that the substrate has a strong role in determining the mobility of the semiconductor. The recorded mobility is significantly different and AFM images were obtained, that confirm the role of grain size and orientation on the recorded mobility of pentacene. - the parasitic capacitance effects due to the superposition (e.g. due to superposition) strongly influence the dynamic behaviour observed in electrical characteristics. The true role of the organic semiconductor in determining the dynamic parameters of the device can be only observed if the structure is free of such capacitance effects.

173
transistors and their fabrication is underway. Also realization of a simple circuit on PET substrates using the already fabricated poly-Ge transistors is in progress and will be reported.

16.3 Transparent Conductors for Flexible Displays: a Performance Study, Sonia Gregg and Jay S Lewis; MCNC - Research & Development Institute, Research Triangle Park, North Carolina.

The development of a transparent conductor that can undergo small radius bending (with relevance for bendable displays) is of great relevance for thin film transistors and their fabrication is underway. We developed test methodologies for electro-mechanical testing of thin film conductive flexible substrates and performed a comparative study using a single ITO layer as benchmark. A cylindrical bending geometry with accurate radius determination was used and performance was investigated as function of high number of cycles (> 1000) for analysis in realistic conditions. The performance of the conductor thin film under bending depends on many parameters, such as substrate thickness, surface modification and neutral plane position. We have explored the properties of multilayer structures containing ITO and of alternative materials suitable to interconnect applications. We found that a judicious choice of layer thickness allows the use of silver sandwiched by ITO ("Dielectric-Metal-Dielectric" structure) to obtain a highly conducting transparent layer with promising bending properties. We will compare the performance of ITO, surface-modified ITO, conductive polymers, and DMD conductors in terms of conductivity, transparency, and performance under mechanical strain and mechanical cyclic bending. This work was supported by the Army Research Laboratory (Contract No. DAAD17-01-C-0085).

16.4 Optical and electrical properties of ionic semiconductor CoOx, synthesized by electrodeposition, Longcheng Wang and Meng Tao; Nanofab Center, Univ. of Texas at Arlington, Arlington, Texas.

Ionic semiconductors offer unique advantages over conventional semiconductors. They can be synthesized by low-cost and low-temperature methods such as chemical bath deposition and electrochemical deposition. The non-directional nature of the ionic bonding reduces defects due to dangling bonds in covalent semiconductors. They are particularly suited for large-area and low-cost applications such as sensors, displays, LEDs, and flexible electronics. We have synthesized cobalt oxide films (CoOx) by using electrodeposition from cobalt nitrate (Co(N03)2) and sodium nitrate (NaNO3). UV-Vis absorption was employed to characterize optical properties of the deposited films. The band gap from the optical absorption data was determined to be between 2.1-2.3 eV. Hall measurements were employed to characterize electrical properties of the deposited films, including conduction type, carrier concentration, and carrier mobility. It was found that all the films were n-type with electron concentration on the order of 10^16 cm^-3 and electron mobility ranging from 30 to 160 cm^2 V^-1 s^-1. The mobility of these films was found to increase with increasing cobalt nitrate concentration. The ionic conductors in CoOx show high ionic conductivity and low electrical conductivity. The electrical conductivity depends strongly upon the particle size. Supported by Petroleum Research Fund.

16.5 Abstract Withdrawn

16.6 Electrical characteristics of edge contact type cell for Phase change RAM, Min Sook Youm1,2, Sun Il Shin1,2, Man Young Sung1,2, Seong Il Kim3 and Yong Tae Kim1; 1Korea Institute of Science and Technology, Seoul, South Korea; 2Korea University, Seoul, South Korea.

PRAM is a promising candidate for next generation memory because of many advantages such as high speed, low power, non-volatility, high density and low cost. PRAM operation relies on the phenomenon that chalcogenide-based materials, such as GeSbTe, can be reversibly switched from an amorphous phase to a crystalline phase by applying an external electric current. The electrical resistivity of the amorphous and crystalline phases differs by a factor of 10^4. However, there are still several problems to be solved before the commercialization of PRAM can be achieved; these include the high operation current (>1.3 mA), the slow set writing speed (>50 nsec), and the thermal fatigue of the phase change material. The operation current level should be reduced to a few hundreds of mA for low-power high-density memory chip production. In this paper, PRAM cell, which has a small and reproducible contact area was fabricated and electrically characterized. The fabricated PRAM cell has improved thermal environment. Normally, contact area is determined by photolithography in the bottom contact type structure. But in the case of edge contact type structure like this, it is determined not only by the photolithography but also by the thickness of bottom electrode.

16.7 The Electronic Circuit Composition and Structure of String for A Novel Braid Electronics-Systems by Kumihimo-Structure, Shigehazu Kuniyoshi and Kunichi Tanaka; Electronics & Mechanical Engineering, Chiba University, Chiba, Japan.

A new integrated circuit concept that forms electronic equipment by the braid structure using the flexible fiber that has equipped the field effect transistor, the solar cell, the light emitting diode, the wiring pattern, etc. is proposed. In this report, the structure of the filamentous body as a basic structure of the braid with various electronic functions was examined. A plastic optical fiber, the glass fiber, and the insulation thin metal line which is enough flexible to construct the kumihimo-structure are used as a base substance of the string for braid. The braid structure described here is constituted by the two sets of two strings that are mutually intertwined and parallel to two planes that lie at right angles. The part where the string crosses each other is used as an electric connection in the new integrated circuit. The field effect transistor and the solar cell formed on a pillar-like fiber are arranged symmetrically with the front reverse side. In order to simplify circuit composition, an active element such as field effect transistors, the electrode pattern for wiring, and the pads for connection are formed on two strings of one group, and the electrode pattern for wiring and the pad for connection only are formed on the strings of the other group. The circuit composition and a concrete structure of the string will be discussed. It will be shown that all logic circuits and flip-flop circuits can be constituted using a few kind of string.

16.8 Titanium-coated Polystyrene Spheres for Electronic Ink, Jun Hee Sung; In Bae Jung, Hyooung Jin Choi and In-Joo Chin; Polymer science and engineering, Inha university, Incheon, South Korea.

Electrophoretic nanoparticles have been widely used in the electronic paper technology, in which the electric field induces electrophoretic migration of the charged nanoparticles through a fluid suspension containing a contrasting dye. Optical characteristics are determined by the refractive index mismatch between the particles and the dispersing medium, and their absorbing coefficient. The electrical characteristics of edge contact type cell for Phase change RAM. Min Sook Youm1,2, Sun Il Shin1,2, Man Young Sung1,2, Seong Il Kim3 and Yong Tae Kim1; 1Korea Institute of Science and Technology, Seoul, South Korea; 2Korea University, Seoul, South Korea.

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The TFT fabrication by PECVD at low processing temperature (180°C) is of great importance because of compatibility with low-cost plastic substrates. The bottom gate silicon TFTs fabricated at 75°C in our lab demonstrated the leakage current of 10⁻¹² A, the threshold voltage of 15 V and the field effect mobility of 10⁻⁴ cm²/Vs [1]. To increase field-effect mobility, we reduced the threshold voltage and reduce the mask count, microcrystalline silicon based top gate TFT was designed. We fabricated TFT at maximum processing temperature of 75°C. Recently developed high quality PECVD silicon nitride as gate dielectric. Microcrystalline silicon was used as a channel. TFTs demonstrated the leakage current about 10⁻¹³ A. The TFT parameters were extracted using the model developed in UW [2]. Devices showed the threshold voltage of 5.10 V, the field effect mobility of 10⁻⁴ cm²/Vs, the subthreshold slope of 5.7 V/decade and the Ion/Ioff ratio of about 10⁵. High source and drain contact resistance of 2 MΩm were attributed to low efficiency of phosphorous doping in amorphous silicon at 75°C, which also limited the Ion value. The mobility is based on a gate length and field effect mobility can be improved by an order of magnitude. The characteristics of top gate TFTs with improved source/drain contacts will be presented. [1] C. Mc Arthur, M. Mettine, A. Sazonov, M. Ellmer, Soc. Symp. Proc. 767 (2005) [2] P. Servati, A. Nathan, J. Vac. Sci. Technol. A 20, 1038 (2002).

Mechanically strained n-Si:H AMOLED driver circuits.

We study ITO island fracture caused by spherical deformation both as 3D bending and 2D fracture of the TFT substrate. The strain is induced by bending of the flexible and rigid TFT substrates, and is measured by the observed changes in the resistance of in situ strain gauges. Mechanical strain impacts the performance of the circuit in terms of its drive current, which may be attributed to the mobility [1] and Fermi energy [2] shifts in the individual TFTs. Here, strain-induced changes are observed in both transient and steady-state behaviour of the TFTs. The effect of strain-induced interactions on transistor pairs, by virtue of (longitudinal or transverse) strain orientation with respect to direction of flow is also examined. Our measurements show that the variation in drive current of the TFT can be as much as ±2% for high strains (10-3). These findings are critical from the standpoint of the long term stability of the drive current, even in matched current mirror circuits, and need to be taken into consideration when designing TFT driver circuits for mechanically flexible AMOLED displays. [1] H. Gleskova, S. Stroucken, W. Schopejko, and Z. Sun, Mat. Res. Soc. Proc. 735, A3131 (2002). [2] W. E. Spear and M. Heintze, Phil. Mag. B 54, 343 (1986).

Electron Beam induced Chemical Modification of amorphous chalcogenides/metal bi-layers and its application.

R K Debnath, N Nusab and A G Fitzgerald; Electronic Engineering and Physics Division, University of Dundee, Dundee DD1 4HN, United Kingdom.

Metal migration and surface modification have been observed in metalcapped amorphous arsenide and antimony based chalcogenide systems such as As2Se3 and Sb2S3 under the irradiation of an electron beam. Surface expansion of order of 5%-35% of the film thickness was observed by applying a 5 to 30 kV electron accelerating voltages. This electron beam induced surface modification (EBM) has been used to produce submicron and nanometre dimensional patterns which will have applications in single stage processing of X-ray masks fabricated on an X-ray transparent silicon nitride (Si3N4) membrane. Masks with a silver deficient trough-like structure have been obtained at lower accelerating voltages (5-10 kV). Silver rich protruding-like structures were obtained at higher accelerating voltages (15-30 kV). These two types of masks exhibit a different X-ray absorption behavior by comparison with the regions unexposed to the electron beam.

Low resistivity ITO films on polymer foils in roll-to-roll fabrication.

Jürgen Deltschew and Gerd Lippold; Solarion GmbH, Leipzig, Germany.

We report on the production of Indium-Tin Oxide (ITO) thin films on polycarbonate plastic foils with excellent optical properties coated with a sheet resistance of below 10 Ohms/square. The production of such low resistivity ITO-coated polymer films is of increasing interest for flexible electronic devices such as displays or solar cells. Using a recently developed DC magnetron sputtering process in a rolling metalized roll coater, resistivities of 1·2·10⁻⁵ Icm, free electron concentrations of 1·2·10¹⁷ cm⁻³ and free electron mobilities of up to 30 cm²/Vs can be reproducibly obtained for 100-300 µm thick ITO films on 25 µm polycarbonate. Optical emission spectroscopy (OES) of the plasma showed a high concentration of oxygen atoms at 10−² cm⁻³, which may be attributed to process parameter optimization. In this communication, we report on the dependence of optical properties (spectral transmission/reflection) and electrical parameters on the process conditions. The ITO films are laterally and vertically homogenous as...
Chemical

Hyuntaek Lim, thickness have been

Department, Portland State University, Portland, Oregon; 2Department of Chemical Engineering, Oregon State University, Corvallis, Oregon; 3School of Electrical Engineering and Computer Science, Oregon State University, Corvallis, Oregon; 4Department of Chemistry, Oregon State University, Corvallis, Oregon; 5Hewlett-Packard Co., Corvallis, Oregon.

Low cost and flexible integrated circuits will enable many new applications for our daily life. Amorphous silicon (a-Si) is the current material of choice for low-cost thin film transistors (TFTs) that are widely used as switching devices in active-matrix liquid-crystal displays. Organic (molecular crystals or polymeric) semiconductors with advantages of flexibility and compatibility with low-cost plastic substrates are another major candidates. Another promising but less explored approach is to use flexible (polymeric) substrates and high performance inorganic materials for the active devices. Inorganic compound semiconductors have advantages of high carrier mobility and excellent long-term stability. The key issue is the requirement of low temperature processing compatible with the low melting temperatures of polymers. The recent advance in soft solution deposition of inorganic materials offers an exciting opportunity to develop large area manufacturing technologies for inorganic TFTs. In this work, we will report our recent development of Metal-Insulator-Semiconductor Field Effect Transistors (MISFET) fabricated on polymeric substrates (Polyimide and PET-Poly(ethylene terephthalate) using a CdS compound semiconductor layer and an oxide-based insulator deposited by low temperature soft solution deposition techniques.

17.2 Novel Nanocast Method of Creating High Aspect Ratio Structure on Thin Flexible Substrate with Nanoparticles. Zhi-Yu Hu1, Anat Burger2, Christen Smith3 and Thomas G. Thundat1, 1Life Sciences Div., Oak Ridge National Laboratory, Oak Ridge, Tennessee; 2MIT, Boston, Massachusetts; 3Clemson University, Clemson, South Carolina.

A novel approach of nanocast is described to create high aspect ratio conductive circuitry on soft thin poly-(dimethylsiloxane) (PDMS). Using gold nanoparticles 3-D conductive circuit structure can be patterned and formed on a thin PDMS flexible substrate. Comparing with thin film deposition method the created circuit demonstrates superior mechanical characteristics and excellent electrical properties. The structure can be as small as 1 mm in letter L shape-like and as thin as a few micrometers. The described process is simple and highly repeatable. This method can also be used to fabricate high aspect ratio structure using other metals, alloys, semimetals, semiconductors, and ceramics.

17.3 A Concept for Flexible Thermoelectric Device. Masatoshi Takada, Keisuke Yokoyama and Masaki Itaya; Department of Mechanical Engineering, Nagasaki University of Technology, Nagasaki, Japan.

We propose a new structure of thermoelectric (TE) device that has a potential to overcome the problems of current TE device. Conventional TE device (Peltier device) consists of p-type and n-type bulk materials connected with solder and mounted on a ceramic substrate. This structure adheres to the basic concept of thermoelectric conversion but has some problems in practice: 1) the device is brittle due to the difference in thermal expansion rate and high stiffness of the materials and the substrate, 2) the structure is ill-suited to mass production, 3) it is difficult to fabricate large size, 4) the device can not be attached to curved surface, etc. The TE device we propose is based on thin film technology. We use a resin film as a substrate on which patterned p- and n-type TE material films are deposited as a fabrication template. On the opposite side of the resin film, patterned metal sheets are attached. The combination of resin film and metal sheet enables us to generate in-plane temperature gradient, which can be converted into electrical potential by the p-n couple, from a heat flux passing through the resin film. We have confirmed the above concept by computer simulation using the finite element method (FEM) and also by experiments. On the basis of the FEM analysis and TE properties of currently used materials, we estimated output electrical power of about 20 W/m² on the assumption that 80K temperature difference is applied between two bottom of the resin film. Details will be presented at the meeting.

17.4 Nano-Scale Devices Embedded in Self-Supporting Polymer Foils. Jie Chen1, Siegfried Klaumuenzer2 and Rolf Koenenkamp1, 1Physics Department, Portland State University, Portland, Oregon; 2Hahn-Meitner Institut, Berlin, Germany.

Self-supporting flexible polymer foils of 10 μm thickness have been structured using irradiation by fast heavy ions and subsequent etching. Very deep, well defined nano-structures can be prepared in this way. These can then be used as templates for the deposition of electric and optical devices. Electron microscopy shows that, void-filling, polycrystalline growth in the polymer films is possible and indicates that a robust hybrid structure on the nano-scale can be fabricated. Metals and Semiconductors can be grown. Electrical experiments on simple devices indicate a low sensitivity to mechanical forces exerted on the foil, suggesting that the embedded nano-devices can be used as reliable sensors in applications with considerable strain on the foils. A variety of addressing schemes for single elements and arrays will be discussed.

17.5 Excimer Laser Crystallization of Sputter Deposited a-Si Films on Flexible Substrates. Yong Hoon Kim, Sung-Kyu Park, Dae-Gyu Moon, Won-Keun Kim and Jeong-In Han; Korea Electronics Technology Institute, Pungtseok, Yumggyi, South Korea.

In this work, the characteristics of excimer laser crystallized polycrystalline silicon (poly-Si) films flexible substrates are discussed. The amorphous silicon films (a-Si) were deposited through rf magnetron sputtering and followed by excimer laser crystallization using XeCl excimer laser (λ = 308 nm). We examined the effects of various a-Si film deposition conditions on the property of annealed poly-Si film. Initially, 50 nm thick a-Si film was deposited by rf magnetron sputtering with temperature at 120°C. The applied power was varied from 50 W to 200 W and the working pressure was varied from 3 to 16 mTorr. As the working gas, pure Ar, pure He and Ar/He mixture gases were used to determine the effects of working gases on the properties of resulting films. During a-Si deposition process by sputtering, impurities such as Ar or He atoms are incorporated in the Si film and may manipulate the structure of as-deposited a-Si and poly-Si during laser annealing process. To control the amount incorporated atoms, working conditions such as applied power, working pressure and Ar/He mixture ratio should be optimized. The Ar content of a-Si film was evaluated from Rutherford Backscatter Spectroscopy (RBS). In the case pure Ar, the Ar content decreased as the working pressure increased. When the working pressure was 5 mTorr the Ar content was about 2 at%. Using Ar/He mixture gas, the Ar content in the films changed as a function of Ar/He ratio. The deposition rate was highest when the pure Ar was used and decreased as the percentage of He was increased. After deposition of a-Si film, excimer laser was irradiated for crystallization. From TEM observation, annealed films are determined as polycrystalline with average grain size of 300 - 300 nm and few grains showed maximum size over 500 nm. Additionally, the characteristics of poly-Si were observed by atomic force microscopy (AFM), Raman spectroscopy (RS), and ultra-violet (UV) reflectivity measurements.

17.6 Polyimide as a plastic substrate for the flexible organic electroluminescent device. Hyuntaek Lim1, Il Kim2, Youngkyo Kim1,2, Chang-Sik Ha1 and Jin Woong Park2, 1 Polymer Science & Engineering, Pusan National University, Busan, South Korea; 2Physics, Imperial College, Blackett Laboratory, London, United Kingdom.

In recent years, interests of transparent flexible plastic substrates with a transparent conducting oxide (TCO) layer such as ITO have been increased in the fields of display and aerospace industry. The plastic substrates may be comparatively used to build lightweight, conveniently portable devices, roll-up displays, or conformable displays, which can be readily attached to windows, instrument panels, or other curved surfaces. Organic electroluminescent devices (OELDs) can also be fabricated on flexible plastic substrates creating the potential to reduce the weight of flat panel displays (FPDs). So far, the use of the flexible substrates for OELDs has been restricted mainly to the polyester films due to their excellent transparent property. However, the plastic substrates till now can be severely damaged at high temperature (200 - 300°C for sputtering method).
during deposition process, mainly due to their intrinsic low thermal and mechanical properties compared with other inorganic or metal substrates. In this study, therefore, it is unfeasible to use a common sputtering method at high temperature. Consequently, reduced electrical resistivity and long-term stability of the ITO surface cannot be achieved and maintained, which is directly related to the performance or reliability of the device. In this work, colorless polyimide substrates with ITO thin films have been prepared with a novel fluorine-containing colorless aromatic PI derived from 2,2′-biphenylhydrazine and a diethyleno-hexahydrophosphine dianhydride (HDDA). The solubility of PI in a polar solvent is high and prone to form colorless or nearly colorless solutions. On the other hand, some inorganic materials, such as SiO2 were recently introduced to OELDs to balance the number of holes and electrons ejected to the emitter layer to achieve high recombination efficiencies. In this work, therefore, the effect of the SiO2 buffer layer on the morphology of the colorless polyimide substrate was also investigated. The SiO2 buffer layer was inserted between the polyimide substrate and ITO layers.

17.7 Micro-scale metallization of Cu and Au on flexible polyimide substrate by electroplating using SU-8 photoresist mask. Nanoparticles have been shown to be useful in the low-temperature sputtering method for forming polyimide films at high temperature. Consequently, reduced electrical resistivity and long-term stability of the ITO surface cannot be achieved and maintained, which is directly related to the performance or reliability of the device. In this work, colorless polyimide substrates with ITO thin films have been prepared with a novel fluorine-containing colorless aromatic PI derived from 2,2′-biphenylhydrazine and a diethyleno-hexahydrophosphine dianhydride (HDDA) and 2,2′-ethyleno-hexahydrophosphine dianhydride (TPHDA). On the other hand, some inorganic materials, such as SiO2 were recently introduced to OELDs to balance the number of holes and electrons ejected to the emitter layer to achieve high recombination efficiencies. In this work, therefore, the effect of the SiO2 buffer layer on the morphology of the colorless polyimide substrate was also investigated. The SiO2 buffer layer was inserted between the polyimide substrate and ITO layers.

17.8 Ink-jetted Silver/Copper conductors for printed RFID applications. Steven Volkman, Shong Yin and Vivek Subramanian; Electrical Engineering and Computer Science, University of California, Berkeley, Berkeley, California.

Low-resistance printed conductors are crucial for the development of ultra-low cost electronic systems such as radio frequency identification tags. Low resistance conductors are required to enable the fabrication of high-Q inductors, capacitors, tuned circuits, and interconnects. Furthermore, for packaging applications it is required to enable fabrication of printed Schottky diodes, necessary for rectification in RFID circuits. Last year, we demonstrated the formation of low-resistance conductive printed structures using gold nanoparticles. In this work we demonstrate, for the first time, techniques for the formation of printed conductors using silver and copper nanoparticles. These are particularly advantageous for several reasons. First, both silver and copper offer a 2X reduction in sheet resistance over gold, resulting in improved interconnect performance and inducer Q. Second, the material costs associated with both silver and copper are expected to be significantly cheaper than gold. Third, the workfunction of silver enables the fabrication of all-printed Schottky diodes with a high forward-bias diode over common printed semiconductor devices. Organic semiconductors. Solutions of organic-encapsulated silver and copper nanoparticles may be printed and subsequently annealed to form low-resistance conductor patterns. We describe novel processes for forming silver and copper nanoparticles, and discuss the optimization of the printing and annealing processes to demonstrate plastic-compatible low-resistance conductors. By optimizing both the size of the nanoparticle and the encapsulant sublimation kinetics, it is possible to produce particles that anneal at low-temperatures (~150°C) to form continuous films having low resistivity and appropriate workfunction for formation of rectifying contacts. This represents a major component required for all-printed RFID.

17.9 High Quality Gate Insulator for Very-Low Temperature Poly-Si TFT Employing Nitrous Oxygen Plasma Process. Kouichi Koyama, Shinya Noui, Shuntaro Kii, Min-Cheol Kang, Sang-Myeon Han and Min-Koo Han; School of Electrical Eng (#56), Seoul National University, Seoul, South Korea.

A high quality gate insulator, which results in a high breakdown field and low flat-band voltage is very important for a thin film transistor (TFT) application. However, the silicon dioxide as a gate insulator deposited at the temperature less than 200°C exhibits rather poor electrical characteristics such as large flat-band voltage and interfacetraps densities. Plasma enhanced chemical vapor deposition (PECVD) are widely used to deposit the gate insulator for very low temperature (<200°C) poly-Si TFT. It should be noted that the large amount of ion-bombardment of the conventional PECVD which may cause a considerable damage at the interface between the gate insulator and the poly-Si film. However, inductively coupled plasma chemical vapor deposition (ICP-CVD) may not cause any ion-bombardment due to the remote plasma process. The purpose of our paper is to report a high quality SiO2 gate insulator for poly-Si TFTs on plastics employing ICP and N2O plasma process. We have proposed N2O plasma pre-treatment in order to reduce the trap densities as well as to improve the electrochemical stability of electronic devices due to its good electrochemical stability and biocompatibility. In this case, the width and conductivity of metal lines are very important for minimizing the size of device. Therefore, the realization of metal interconnects and microelectrodes is essential for the scale down of micrometers on the flexible substrate is very interesting. In this work, micro-scale metallization lines of Cu and Au were fabricated on the flexible substrate by electroplating using the patterned mask of a negative-tone SU-8 photoresist. Surface of polyimide substrate was treated by O2/Ar atmospheric plasma for the improvement in adhesion between Cr layer and polyimide and in-situ sputter-deposition of 100-nm-thick Cu seed layers on the sputter-deposited 50-nm-thick Cr adhesion layer was followed. SU-8 photoresist was spin-coated and patterned by photolithography. Electroplating of Cu and Au lines, removal of SU-8, and selective wet etch of Cr adhesion and Cu seed layers were carried out. Metallization lines of Cu were fabricated using a sulfuric acid electroplating solution at room temperature on the Cu seed layer. Microelectrodes of Au were electroplated using a noncyanide electroplating solution on the electroplated Cu lines or on the Cu seed layer. Gap between the Cu and Au lines was successfully filled by spin-coating of polyimide. Micro-scale Cu and Au metal lines with gap filling on the polyimide substrate with the thickness of 6-12 μm and the aspect ratio of 1:3 were successfully fabricated.


The reduced melting point and high solubility of inorganic nanoparticles have been shown to be useful in the low-temperature solution-based fabrication of semiconductor devices. These devices have been demonstrated using various techniques to form inorganic logic elements, multi-layer structures, and MEMS. Here we report a new technique known as offset liquid embossing that is used to print the nanoparticle inks. Structures created include multiple layers of gold and spin-on-glass printed without the need for etching or planarization, and 100 nm resolution.


Large area n-Si:C:H imagers fabricated on plastic substrates at low temperatures are strong candidates for flexible electronic. They can be manufactured, at low cost, taking profit from the amorphous silicon technology. Large area p-i-n image sensors made of an flexible substrates (PET) were produced at low temperatures (110°C) by PE-CVD and compared with similar sensors deposited on glass substrates. The same sensing element structure ITO/p-Si:C:H/i-Si:C:H/n-Si:C:H/Al or ITO was used for both devices. The imager is an optically addressed read-write device based on a large area (4x4 cm2) sensing element and a scanning reader. Imaging is performed in a simultaneous write-read two step process: the write exposure, which converts the charge stored in the nanocrystals that remain confined at the illuminated regions and the optical read, which performs the charge to current conversion by detecting the photocurrent generated by a moving point scanner. The output signal at the XY coordinates is amplified and recorded as an electronic output.

177
image whose magnitude depends on the light pattern localization and intensity. No charge transfer to move the packets of charge within the sensor is needed during the image acquisition process. In this work the efforts are focused mainly on the optimization output characteristics of the sensor when fabricated on plastic substrates. The role of the sensor configuration and readout parameters on the image acquisition process is found to be strongly affected by the optical-to-electrical characteristics show a high quantum efficiency, broad spectral response, and reciprocity between light and image signal. A numerical simulation supports the imaging process. First results show that when high intensity images are processed the sensor deposited on flexible substrates present a high image-blur effect due to an increased lateral stress between active layer and plastic substrate is reduced. And the stress depends on the layer thickness, we has studied the characteristics of a-Si:H TFT on plastic substrate as a function of the SiNx layer thickness. To reduce the stress, we adopted the double layered gate insulator, the organic material as a 1st gate insulator was coated, and the 2nd gate insulator of SiNx was deposited by PECVD at 150°C. The a-Si:H and a n+-a-Si:H for ohmic contact layer were consecutively deposited on top of the SiNx. A voltage was used to form the ITO. As SiNx thickness is decreased from 400 nm to 50 nm, the sputtered de magnetron aluminum doped zinc oxide (ZnO:Al) for use as substrates present a high image-blur effect due to an increased lateral transport near the ITO/p interface. At the illuminated regions the photogenerated holes drift to the ITO and lateral leakage occurs by conduction through the ITO along the interface between the active layer and the ITO. To avoid this effect a higher resistive p-layer has to be used and also the scanner and the optical image should be kept on opposite sides.

17.12

An a-Si:H TFT on plastic is of increasing interest for mobile applications. One of the key issue for an a-Si:H TFT on plastic is to lower the substrate temperature. However, if the process temperature is less than 200°C for use of PES(Polyethersulfone), the TFT exhibits low field mobility, high threshold voltage and a large threshold voltage shift due to mechanical stress at the interface between active layer and plastic substrate. That is the stress would be generated by the difference in the coefficient of thermal expansion between active layer and plastic substrate. This stress makes active layer cracked and peeled from the plastic substrate. Since this kind of stress depends on the layer thickness, we has studied the characteristics of a-Si:H TFT on plastic substrate as a function of the SiNx layer thickness. To reduce the stress, we adopted the double layered gate insulators, the organic material as a 1st gate insulator was coated, and the 2nd gate insulator of SiNx was deposited by PECVD at 150°C. The a-Si:H and a n+-a-Si:H for ohmic contact layer were consecutively deposited on top of the SiNx. A voltage was used to form the ITO. As SiNx thickness is decreased from 400 nm to 50 nm, the stress between active layer and plastic substrate is reduced. And the field effect mobility is increased from 0.1 to 0.42 cm²/Vs. Threshold voltage is decreased from 5 V to 1.5 V. we will present our result in detail with a mechanism at the symposium.

17.13
Near-substrate plasma effects on the properties of de magnetron sputtered aluminum doped zinc oxide.


The effects of near-substrate plasma density are studied for reactively sputtered dc magnetron aluminum doped zinc oxide (ZnO:Al) for use as a transparent conductive oxide. Plasma density variation is achieved using an unbalanced magnetron and external Helmholtz coils. Using this method the substrate ion-to-neutral flux ratio was varied from 0.2 to about 3.5. The ZnO:Al films were characterized by resistivity, transmission, Hall effect, and theta-two theta x-ray diffraction. At low substrate temperatures (< 88°C) increased near-substrate plasma density improved the film quality dramatically, while for higher substrate temperatures (> 135°C) no improvement was observed. It was verified that the improvement of properties at lower substrate temperature was not due to substrate heating by the plasma. In addition, it is argued that the observed improvement is not due to an increase in overall crystalline quality, but rather is likely due to chemical effects. The implications for low temperature growth of ZnO:Al on temperature sensitive substrates such as plastics will be discussed.

17.14
Flexible Substrate Based Gas Sensors for Air Pollution Monitoring. Serghei Dmitriev1, Gheorghe Duca1, Igor Dementiev2 and Alexander Craciun1; 1Industrial and Environmental Chemistry, Moldova State University, Chisinau, Moldova; 2Department of Physics, Moldova State University, Chisinau, Moldova.

Last years the considerable attention of researchers is directed on the creation of different type flexible based electronic devices for very different application. In the given report we present results of investigation of possibility to produce gas sensors on flexible substrates (polymer roll base). As gas sensitive materials were chosen glass chalcogenide semiconductors on the base of solid solutions of (As2S3)1-x(As2Se3)x (where x=0, 0.3, 0.5, 0.7 und 1.0) and also solid solutions of As-Ti-Se system. Thin films of the mentioned above materials were deposited on laval’s roll film by means of thermal evaporation for wave lengths 110-155 pm. At the sensitivity of 1-2 pm the deposited layers are possessed the specific resistance in the range of 1010-1014 Ohm. Cm on dependence on chemical composition. The change of conductivity of these films in the presence of gases as well as atmospheric is analyzed. The transfer characteristic of gas sensors depending on percentage of SiO2 in the layer and the ITO. To avoid this effect a higher resistive p-layer has to be used and also the scanner and the optical image should be kept on opposite sides.

17.15
Polymeric Electrochromics are Ready to Use. Gursel Sonmez, Clifton K. F. Shen and Fred Wudl, Chem. & Biochem., UCLA, Los Angeles, California.

The ability to have three complementary colors, red, green and blue constitutes an important step forward for the use of conducting polymers (CP) in polymeric electrochromic devices. Until now, these three legs of color space are completed, all other colors can be obtained according to color mixing theory. Although many red and blue colored polymers in their neutral form have been reported, green colored CP’s were not reported till now. This is likely due to the difficulty in obtaining the necessary absorption bands visible to reflect green. The absorption at only one dominant wavelength is required to obtain blue or red colors, these can be obtained easily by tuning the CP’s band gap. For a green color two absorption bands (red and blue) are required. While these chromophores absorb red and blue in the neutral form of the polymer, they should also deplete together when the polymer is oxidized. However, the difficulty of controlling both chromophores at the same time with the same applied potential to create and deplete two absorption bands in the visible from the same polymer, make a green neutral polymer almost impossible to realize. Recently, we have initiated a study to obtain a CP which reflects green light in the neutral state and is transparent in the oxidized state. We believe that the goal could be achieved with the synthesis of a polymer backbone containing two well-defined, conjugated systems such as organic polymers has been severely limited. Therefore, it is very difficult to fabricate a flexible display with carbon nanotubes (CNTs) due to their high synthesis as well as processing temperature.

Direct Synthesis of Carbon Nanotubes on Organic Polymer Substrates. Eun Hwa Hong1, Kun-Hong Lee1, Hyung Suk Kim2 and Chan-Gyung Park2; 1chemical engineering, POSTECH, Pohang, South Korea; 2materials science and engineering, POSTECH, Pohang, South Korea.

Since the discovery of carbon nanotubes (CNTs), various methods of the synthesis of CNTs have been reported; arc-discharge, laser ablation, chemical vapor deposition, flame synthesis and Smalley’s recent invention of high pressure CO(HIPCO) process. None of them is able to synthesize CNTs at low temperature (say, less than 200°C), so that the incorporation of CNTs with low melting point materials such as organic polymers has been severely limited. Therefore, it is very difficult to fabricate a flexible display with carbon nanotubes (CNTs) due to their high synthesis as well as processing temperature. Here, CNTs were directly synthesized on organic polymer substrates by applying microwave heating of CNT precursors. The microwave heating of CNT precursors was achieved using microwave absorber and they were applied to flexible field emitter arrays. Since the microwave energy is selectively absorbed by the catalysts, not by the substrates, local heating occurs, resulting in the CNT synthesis even on the organic polymer substrates, and degradation of the polymer material is minimum. In our work, microwaves were directly irradiated on the catalyst particles on organic polymer substrate. Acetylene was used as a monomer that would afford two conjugated chains was designed and synthesized. Electrochemically prepared poly(1) showed high green color saturation, fast switching property and extreme stability that makes this material promising for completion of the deficient third leg of the color space and also opens the way to fabricate polymeric RGB electrochromic devices.

Flexible Substrate Based Gas Sensors for Air Pollution Monitoring. Serghei Dmitriev1, Gheorghe Duca1, Igor Dementiev2 and Alexander Craciun1; 1Industrial and Environmental Chemistry, Moldova State University, Chisinau, Moldova; 2Department of Physics, Moldova State University, Chisinau, Moldova.

Last years the considerable attention of researchers is directed on the creation of different type flexible based electronic devices for very different application. In the given report we present results of investigation of possibility to produce gas sensors on flexible substrates (polymer roll base). As gas sensitive materials were chosen glass chalcogenide semiconductors on the base of solid solutions of (As2S3)1-x(As2Se3)x (where x=0, 0.3, 0.5, 0.7 und 1.0) and also solid solutions of As-Ti-Se system. Thin films of the mentioned above materials were deposited on laval’s roll film by means of thermal evaporation for wave lengths 110-155 pm. At the sensitivity of 1-2 pm the deposited layers are possessed the specific resistance in the range of 1010-1014 Ohm. Cm on dependence on chemical composition. The change of conductivity of these films in the presence of gases as well as atmospheric is analyzed. The transfer characteristic of gas sensors depending on percentage of SiO2 in the layer and the ITO. To avoid this effect a higher resistive p-layer has to be used and also the scanner and the optical image should be kept on opposite sides.
SESSION 18: Flexible Displays: OLEDs
Chair: Babu Chalamala
Thursday Morning, April 15, 2004
Room 2018 (Moscone West)

8:30 AM *18.1 Flexible PLED displays and related technologies.
Giovanni Nistico, C.A.H. Mutsaers, O.J.A. Buik, F.C. Duineveld,

Flexible, free shape displays are the enabling technology for new robust, lightweight, extremely thin, portable electronic devices. Polymer Light Emitting Diodes (PLED) are especially suited for these applications, due to their fast response time, light weight, high luminous efficiency and viewing angle performance. On the other hand, PLED displays are extremely sensitive to moisture and oxygen. Substrate materials provided with high performance hermetic and conducting layers are therefore an essential component for manufacturing these flexible devices. Polymer based substrates provide the necessary mechanical flexibility; they also require several thin, brittle, functional inorganic layers such as diffusion barriers and transparent electrodes. The structural integrity, dimensional stability and thermal properties of the substrate stack are crucial to insure device functionality and reliability. For polymer-based substrate several effects have to be taken into account to successfully perform classic photolithographic steps. Ink-jet printing is a critical enabling technology for flexible PLED displays, providing a cost effective method to synthesize solution based polymers onto a flexible substrate, allowing for multi-color devices. On the other hand, LIP must meet several challenges, especially to comply with industrial applications. For example, accurate landing position of the droplets to form homogeneous hole-transport and electroluminescent layers, and well wetting characteristics of the substrate must be obtained with reliable high throughput techniques.

9:00 AM 18.2 Study of Water Vapour Transport Properties of Different OLED Package Designs.

A highly sensitive water vapour permeation measurement technique for organic light emitting display applications is demonstrated. Calcium is used as a sensor to detect the water vapours. Electrical properties of the sensor are measured to monitor the calcium degredation. The amount of the calcium hydroxide is detected by measuring the change in electrical properties of calcium. The sensitivity of this measurement is high. For the measurement of water vapour transmission rates is less than $10^{-6}$ g/m<sup>2</sup>/day and can be carried out in a wide temperature range from 30°C to 95°C and up to 95% relative humidity. In this study, the water vapour permeation mechanism in various encapsulated organic light emitting devices and degradation phenomenon were investigated. Water vapour transport rates and diffusion coefficients of flexible plastic and glass based packaged OLED structures are quantified and related to the OLED lifetimes. A novel OLED packaging technique is demonstrated with an improved OLED lifetime.

9:15 AM 18.3 A reflectivity-based metrology to quantify moisture transport through barrier layers for OLED applications. Bryan D Vogt<sup>1</sup>, Hae-Jeong Lee<sup>1</sup>, N M Rutherford<sup>2</sup>, L Moro<sup>2</sup>, Sushil K Satija<sup>2</sup> and Wen-li Wu<sup>2</sup>;<sup>1</sup>Polymers Division, NIST, Gaithersburg, Maryland;<sup>2</sup>Center for Neutron Research, NIST, Gaithersburg, Maryland;<sup>3</sup>Vitex Systems, Inc., San Jose, California.

Moisture is known to have a detrimental effect on the lifetime of display devices based on organic light emitting molecules. It is essential for the industry to be able to predict moisture barrier lifetimes in future OLED devices and there are major ongoing efforts in this area with a target permeation rate lower than $10^{-5}$ g/m$^2$/day. Current technology, e.g. ASTM F372 or MOCON 3/31, only has a sensitivity of $10^{-5}$g/m$^2$/day, which is two orders of magnitude improvement over the current technology, which can be resolved using reflectometry. However, problems in resolving the thickness change of the polymer film can arise if the barrier is a multilayered stack with spacing comparable to the polymer thickness. Alternatively, exploiting the thickness resolution of reflectometry will be discussed.

9:30 AM *18.4 Integration of Organic LEDs and Pentacene OTFTs on Plastic Substrate.
Chang-Kun Song<sup>1</sup>, Yong-Xian Xu<sup>1</sup>, Hyun Sook Byun<sup>1</sup>, Gi Seong Ryu<sup>1</sup>, Myung Won Lee<sup>2</sup>, Kwang Hyun Kim<sup>1</sup> and Chang Hee Lee<sup>2</sup>;<sup>1</sup>Dept. of Electronics Eng., Dong-A University, Busan, South Korea;<sup>2</sup>Dept. of Physics, Inha University, Incheon, South Korea.

Recently, organic thin film transistor (OTFT) are attracting much attention because of their noble application such as flexible display, and flexible RF-Ok. Fused organic semiconductors, such as pentacene, are prevailing as active layer. The pentacene as active layer produce a remarkable performance with the mobility of 5cm<sup>2</sup>/V.s so that the realization of such applications has been more convenient. However, there still exist several issues which should be addressed for the application on plastic substrates. The above all issues of dielectric is the most critical. The gate insulator should provide a smooth surface for the high quality organic film deposited above it and additionally it should be insulating enough to reduce the leakage current through the gate for the process compatibility with plastic substrate the organic dielectric layers are widely applied. Most of the present organic dielectric layers exhibit a serious problem of the high leakage current, resulting in the typical on/off current ratio of 103. In this paper we designed and fabricated a prototype of OLED display panel driven by pentacene OTFTs on a plastic substrate. PET was employed for the substrate on which ITO gate contact layer was deposited. For the gate dielectric of OTFTs the pentacene OTFTs the organic and inorganic hybrid structure such as PVP/SiO<sub>2</sub>/PVP was applied in order to enhance the mobility as well as to reduce the leakage current. PVP layer usually provides a high mobility due to the smooth surface but it exhibits a large leakage current. The large leakage current has been compensated by the high insulating SiO<sub>2</sub> layer, which was deposited by ion beam sputter. Pentacene film was grown by OMBD system. We analyzed the growth mechanism in detail and obtained an optimum growth condition for high quality crystal film. Especially, we developed a new photolithography process to pattern the organic thin film, which is characterized by using a water-soluble photoresist and thus avoiding the damages to organic film originated from organic solvents employed in the conventional photolithography process. For the measurement of water vapour transport properties of different OLED structures are quantified and related to the OLED lifetimes. A novel OLED packaging technique is demonstrated with an improved OLED lifetime.

10:30 AM *18.5 Thin Film Permeation Barriers for Flexible OLED Displays: Technology and Challenges.
Jay Lewis and Dorota Temple; MCNC Research and Development Institute, Research Triangle Park, North Carolina.

It is widely accepted that the development of flexible organic light emitting device (OLED) based displays will require thin film permeation barriers to prevent degradation due to moisture and oxygen. The challenges in thin film permeation barrier technology will be reviewed, including the various display architectures, permeation measurement techniques, barrier materials and deposition technologies. It will be shown that significant progress has been made
in the development of thin film permeation barriers with sufficiently low permeation rates. But additional challenges exist if the permeation barriers are to be used with a truly flexible display. Because permeation barriers typically include brittle inorganic thin films, a critical aspect of flexible permeation barriers is that they be robust enough to survive under the flexing conditions present for the application. Therefore, a layer of brittle inorganic permeation barriers, if a single microcrack will result in catastrophic failure of the barrier film. We will present data showing the limitation of selected materials and barrier architectures under flexing, and discuss the challenges in realizing a truly flexible OLED display. Various approaches to realizing flexible permeation barriers will be discussed. This work was supported by the Army Research Laboratory (Contract No. DAAD17-01-C-0085).

11:00 AM 18.6
The role of a thin polymer interlayer in improvements of device efficiency and lifetime of polymer light-emitting diodes. Ji-Seon Kim⁴, Grzegorz Pschenitzka⁵, Da-Yean Song⁶, John Burroughes⁷ and Richard Friend⁴,⁵,¹ ¹Physics, Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom; ²Cambridge Display Technology Ltd., Cambridge, United Kingdom.

We report that adding a thin (less than 10 nm) polymer interlayer between a PEDT:PSS hole-transporting layer and an emissive semiconductor layer improves significantly both the device efficiency and the lifetime of RGB polymer light-emitting diodes (LEDs). The interlayer is spin-coated directly on the top of the PEDT:PSS layer from a TFB, poly(2,7-(9,9-di-n-octylfluorene)-alt-(1,4-phenylene-((4-sebutylphenyl)imino)-1,4-phenylene)), (The Dow Chemical Company) solution. With the interlayer, the quantum efficiency (EQE) increases from 0.7 % (0.4 cd/A at 3.7 V) to 1.9 % (1.0 cd/A at 3.3 V) at 100 cd/m² for red-emitting LEDs and from 1.9 % (6.2 cd/A at 3.4 V) to 3.0 % (1.0 cd/A at 3.0 V) at 1000 cd/m² for green-emitting LEDs. Without this interlayer, over 40 % of the EQE was lost in both the DC and pulsed lifetime of the devices. In this presentation, we will discuss the main role of this thin polymer interlayer in terms of its efficient exciton blocking properties at the PEDT:PSS/ emissive semiconductor interface. The exciton lifetime of the emissive semiconductor, which is significantly quenched at the interface with PEDT:PSS, recovers by inserting the interlayer. In particular, the thinner the emissive semiconductor layer the more complete the recovery from exciton quenching was observed. This blocking property of the interlayer from exciton quenching plays an important role in improving the device performance.

11:15 AM 18.7

Bridging the gap between materials research and product development is a challenge in all aspects of materials science and engineering. This is because materials research is by very nature upstream and product development downstream. The injection of the two aspects of technology is not a straightforward process. This issue has been plainly illustrated by the length of time and the sheer size of investment required for organic light emitting diode (OLED) display technology to be commercialized. Moreover, flexible display products are unlikely to arrive for another two to three years. In particular, the sensitivity of these electronic materials to the environment and the operating lifetime requirements of devices place high demands on the choice of material systems. This presentation will cover two themes. Firstly it will provide an update on the technical work being performed at IMRE on flexible OLED technology, focusing on the progress with demonstrator devices that aim to bridge the gap between upstream research and product development. In particular, details of the demonstrator devices comprising both fixed logo and passive-matrix driving will be discussed, showing how they may be used as a vehicle to consolidate research, develop processes and fire the imagination of a nation. Secondly, the presentation will consider the relevance of this research and development to local industry and how such an activity is facilitating and promoting the growth of a new manufacturing sector. This will be described in both the context of the need of local industries and the role of multinational companies, with a value chain analysis focusing LED just-before-the-transtorm of the polymer, the electro-luminescence (EL) is dominated by the lowest energy dye, so that only red or green EL results from the region where red or green dyes are printed[2]. A blocking layer (BL), an electron transport layer (ETL) and a cathode layer complete the structure. Unlike most patterned devices, where the ETL is uniform and ETL patterned, in this case HTL is patterned with dyes with uniform ETL on top. The optimum dye concentration in the vylon is affected by loss of dyes during the dye source patterning, which involves annealing at an elevated temperature to a pre-patterned film. Excess dye concentration leads to quenching of excitons in the final devices. This concentration was optimized using SIMS, PL and EL, and was about 65 % (by weight) in the vylon to give a final device concentration of about 0.3 %. Device efficiency was 1.0 cd/A at 3.3 V. Using a three-color passive-matrix test array with 300 mm x 1 mm RGB subpixels was demonstrated. J. F. Pschenitzka and J. C. Sturm, Appl. Phys. Lett. 78 (17), 2584 (2001). 2. J. F. Pschenitzka and J. C. Sturm, Appl. Phys. Lett. 79 (17), 4354 (2001).

SESSION 19: Materials and Processes for Flexible Electronics I
Chairs: David Brennen and Giovanni Nisato
Thursday Afternoon, April 15, 2004
Room 2018 (Moscone West)

1:30 PM *19.1

Printing methods familiar to the graphic arts industry allow the placement of specially designed electronic materials at high speed and low cost. Processes such as offset lithography, screen printing and gravure printing have advantages in aspects of process capability when compared with ink jet printing. For both historical and pragmatic reasons, the patterning and layering capability of printing has been limited to such as the resolving power of the human eye. Experiments have been conducted to benchmark existing capability of these processes and materials on flexible substrates. Such experiments will provide a foundation for exploring the viability of existing printing infrastructure for the mass production of commercial products. In addition, improvements in these electronic materials and the mechanics of printing processes may provide significant advancement of future application capability.

2:00 PM 19.2
Oxide Semiconductors for Flexible Electronics. Peter F. Garcia, Robert McLean, I. Malajovich and Michael Reilly, Research and Development, DuPont, Wilmington, Delaware.

Inorganic semiconductors provide an enabling technology for high performance, low cost, robust electronics on flexible plastic substrates. In this paper we discuss progress in developing inorganic oxide semiconductors as thin film transistors (TFTs) for flexible electronics. Besides improvements in ZnO TFTs, we present new results for In203-based TFTs. We prepared oxide semiconductors by rf magnetron sputtering from oxide targets on substrates maintained near room temperature. ZnO and In203 sputtered films were determined to be polycrystalline (XRD) with grain size (AFM) smaller than 40 nm. Both films were optically transparent in the visible, which may be a particular advantage for addressing of displays. D1T devices were fabricated on a gate dielectric of A12O3 made by e-beam evaporation and on the thermal oxide of Si. For In203 TFTs, we found that sputtering at 4 mTorr (Ar...
Flexible Magnetics for plastic substrates: magnetic lithography, magnetic nanostructures and other applications.

Flexible Magnetics stands for design, fabrication and characterization of magnetic devices and systems built on thin flexible substrates. Although device and system functionality is magnetic in nature, flexible magnetics draws interesting parallels to flexible electronics, especially in fabrication challenges on plastic substrates. Some of these challenges include substrate surface quality and maximum processing temperature, tooling issues related to mechanical properties of flexible substrates, adhesion of thin films deposited on plastics, as well as thermal stability of fabricated devices. One application of flexible magnetics, relevant for information storage industry is magnetic lithography. Magnetic lithography is a process qualitatively analogous to contact optical lithography which transfers information from a nanopatterned magnetic mask (analog of optical photomask) to magnetic media (analog of photoresists), and is interesting for applications in instantaneous parallel magnetic recording. The magnetic mask consists of nanopatterned soft material (FeNiCo, FeCo) on a thin flexible plastic substrate, typically Polyethylene Terephthalate (PET) or polyimide. When uniformly magnetized, the magnetic mask is brought into intimate contact with the magnetic substrate, an externally applied magnetic field selectively changes the magnetic orientation in the areas not covered with the soft magnetic material. Flexible substrate of the magnetic mask offers superior compliance to magnetic media which is likely to have imperfect flatness and surface particulate contamination. We discuss nanofabrication challenges of magnetic masks on plastic substrates, including electron beam lithography, electroplating and lift-off processing on the nanometer scale, adhesion of metal thin films on PET and polyimide substrate, and release of plastic films from rigid substrates used during the processing. We present results on fabricated magnetic masks, and magnetic force microscopy images of the magnetic transition patterns. Besides fromation of magnetic nanostructures and devices on plastic substrates, we also present our results on nanoscale patterning of plastic thin film. We will present our results on fabrication of sub-100 nm scale nano-channels in polyimide films, as well as assembly of ordered arrays of polyimide nano-dots. Nanoscale patterned plastic films are interesting for its potential application in patterned media, as well as for its application in micro- and nanofluidics, due to the mechanical functionality and biological inertness of plastic materials. We will discuss interesting biosensing systems that may result from synergy of magnetic nanostructure functionality, electronic control and patterned nanofluidic channels on plastic substrates.

Performance of barrier layer for flexible substrate using PVD deposition process.

In this presentation, we discuss the PVD process and its use for deposition of insulators on flexible substrates. Specifically, by promising results on the WVTR through PEN substrate coated with a proprietary thin film layer are presented and compared with results of the same coating on other flexible substrates such as PES and others.

Development of the Electrophoretic Display Module with High-Performance Organic TFT Array on PES Plastic Substrates.

Organic thin-film transistors (OTFTs) have been rapidly developed in the past few years. Especially, it is important to develop new gate dielectrics and passivation materials as well as organic semiconductors for increasing the mobility and improving the stability of organic transistors. Recently, a variety of organic gate dielectrics have been introduced besides conventional inorganic insulators such as SiO2 and SiNx. The use of organic gate dielectrics susceptible to solution coating leads to not only improve the performance of TFT but also promise low-cost and large electronic device application. We have developed the novel organic insulators based on polystyrene and polyacrylic that are very clear and photo-definable. These organic gate dielectrics were evaluated to give a strong chemical resistance in several etchants and strippers. OTFT devices were fabricated as the top contact structure. The gate electrodes were created by deposition and patterning Cr layer on a PES plastic film. Next, our gate dielectric materials were applied, and then pentacene and Au electrodes were evaporated on these layers. They operated with mobilities about 3.5 cm2/Vs and on-off current ratio over 10E5. On the other hand, organic passivation material has been developed to maintain the TFT performance and stability. The OTFT array protected by the passivation layer showed no noticeable TFT performance degradations before and after passivation process. 4-inch sized TFT array on the PES plastic film could be successfully fabricated using a couple of organic gate dielectrics and passivation materials based on the result of unit cells. This plastic OTFT backplane was laminated with electrophoretic film and drove the electrophoretic display; the OTFT based electrophoretic display module has the number of 120 x 10 pixels in which pixel size is 500 µm x 500 µm. This technology could be extended to new display applications such as flexible e-papers and e-books as well as conventional slim mobile displays in the near future.

Roll-to-roll processes for the manufacturing of Microcup® electronic paper.

Roll-to-roll processes for the manufacturing of Microcup® electronic paper. Yi Shung Chaug, Jarrod Haubrich, Mike Sereda and R.C. Liang; SiPix Imaging Inc., Fremont, California.

Flexile Electronics for Space Applications.

Flexible Electronics for Space Applications. Erik Brandon, NASA Jet Propulsion Laboratory, Pasadena, California.

Enhancement of the electrical properties of ITO deposited on polymeric substrates by using a ZnO buffer layer.

Erika Maria Corina Fortunato, Carlos Nunes de Carvalho, Ana Pimentel, Guilherme Lavareda, Alexandra Goncalves, Antonio Marques and Martina Rodrig; Materials Science, FCT-UNL, Caparica, Portugal.

Transparent Conductive Oxides (TCO) have a wide range of applications, ranging from transparent electrodes in optoelectronic devices, heat resistant surfaces or even in solar cells. In all these applications a worldwide rule already accepted by the scientific community must be verified: better transmittance translates to lower resistivity. Nevertheless the already obtained values for optical transmittance around 90% are difficult to increase, because we are close to the theoretical optical limits of these oxides. The other possibility is by reducing the electrical conductivity (sigma). Concerning this point and since sigma = nqμ, the only way to achieve such goal is by increasing the carrier concentration (n) of the electron mobility (μ). The carrier concentration is limited to the maximum solid solubility of the dopant, while the electron mobility depends more on the structural defects, grain size and also on the dopant concentration. In this paper we present results of ITO deposited at room temperature by Plasma Enhanced Reactivity Thermal Evaporation on intrinsic and amorphous (buffer layer) deposited by rf magnetron sputtering on polymeric substrates.
as an efficient way to improve the electronic mobility of ITO without loosing the optical properties. The preliminary results indicate that it is possible to decrease the resistivity of the ITO film by a factor of 10, reducing the magnitude. In this paper a correlation between the thickness of the buffer layer and the electrical, morphological and structural properties of the ITO is discussed.

SESSION 110: Poster Session: Flexible Materials and Devices Tuesday, April 15, 2004 8:00 PM Salons 8-9 (Marriott)

110.1 Pentacene Organic TFT with \text{Al}_{2}O_{3}, Gate Dielectric Deposited using Atomic Layer Deposition Method. YongWoo Cho1, JinSeong Park2, Joannis Kymissis2, Annie Wang3, Roy G. Gordon4 and Akintunde A. Akinwande5, 1Microsysstems Technology Lab, Massachusetts Institute of Technology, Cambridge, Massachusetts; 2Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts; 5Department of Chemistry and Chemical Biology, Harvard University, Cambridge, Massachusetts.

The field-effect mobility of pentacene OTFT has improved to a value comparable to that of a-Si TFT. However, for applications such as flexible electronics and Electrotextile, the operating voltage of pentacene OTFTs required to obtain sufficient current modulation (high on/off ratio) is still high (20 100V). The high operating voltage is due to the low transconductance, \( g_{m} = 10^{-7} \), which is about 2 3 times higher than that of parylene-C or SiO2 film that is often used as a gate dielectric for pentacene OTFT. For the flexible electronics and Electrotextile application, the film should be formed at low temperature. Using Atomic Layer Deposition (ALD) method, an \text{Al}_{2}O_{3} film with high quality was deposited at low temperature ( 150°C). In ALD, the film growth by sequential and self-limiting surface reactions is able to control the film thickness precisely and allows for excellent conformal growth, which is desirable for flexible electronics and Electrotextile applications. In addition, ALD can tailor the composition and structure of the film, such as nanolaminate, so as to have the desired properties. The ALD \text{Al}_{2}O_{3} films were grown using water, H2O, and trimethylaluminum(TMA), Al(CH33). We fabricated pentacene OTFT using the ALD \text{Al}_{2}O_{3} film as a gate dielectric. For electric fields below 2 MV/cm, the leakage current density of 10^{-7} A/cm2. Above 2 MV/cm, the leakage current density increased to 10^{-4} A/cm2 and catastrophic breakdown occurred at 8 MV/cm. The field effect mobility of the OTFT with ALD \text{Al}_{2}O_{3} gate dielectric, which is similar to that of the OTFT with parylene gate dielectric fabricated at the same time. On-current at 80 V of gate voltage was 3X10^{-4} A and 1.5X10^{-4} A for the 200 nm thick ALD \text{Al}_{2}O_{3} and 140 nm thick parylene gate dielectric, respectively. Therefore, the film thickness of the OTFT was 1250 nm and 59 nm, respectively. The on-current for pentacene OTFT with ALD \text{Al}_{2}O_{3} is about twice the on-current for pentacene OTFTs with parylene gate dielectric even though the ALD \text{Al}_{2}O_{3} gate dielectric of the OTFT is thicker.

110.2 Molecular weight dependent mobilities in polymer diodes and transistors. Chia Tian Goh1, R. Joseph Kline2, Michael D. McGeehen1, Ekaterina N. Kadnikova1, Jinsong Liu2 and Jean M. J. Frechet2. 1Department of Materials Science & Engineering, Stanford University, Stanford, California; 2Department of Chemistry, University of California - Berkeley, Berkeley, California.

Semiconducting polymers are strong candidates to be used as the active material in flexible light-emitting diodes, transistors and solar cells because they can be deposited from solution at low temperature. Regioregular poly(3-hexyl-thiophene) is currently one of the best semiconducting polymers for charge transport. It has been used to make field effect transistors with a mobility of 0.1 cm2/V·s and photovoltaic cells with an energy conversion efficiency of 3.5 %. Reported values for the mobility of this polymer vary widely. Our studies show that some of the variation in mobility can be attributed to well known parameters, such as regioregularity, casting solvent and dielectric surface treatment, but that a lot of the variation is also attributable to changes in molecular weight. In field effect transistors, where current travels in the plane of the film, we find that the mobility increases from 6.8 x 10^{-5} to 2.8 x 10^{-5} cm2/V·s as the molecular weight increases from 3.2 to 11 kg/mole. In diodes, where current travels perpendicular to the plane of the film, we find that the mobility increases from 1.3 x 10^{-5} to 3.3 x 10^{-5} cm2/V·s as the molecular weight in increased from 2.9 to 31 kg/mole. Furthermore, we find that the mobility is field dependent for low molecular weight films, but that it is not field dependent for high molecular weight films. Temperature dependent mobility measurements show that the activation energy for hopping decreases from 143 meV to 126 meV as the molecular weight is increased. X-ray diffraction and atomic force microscopy measurements show that the films are composed of nanocrystalline rods. Collectively, these findings suggest that charge transport is hindered in low molecular weight films by charge trapping at the boundaries between crystals. These experiments highlight the importance of controlling the molecular weight of semiconducting polymers and shed light on how charge travels through polymer films.
We have prepared organic electroluminescent devices with improved efficiency and lower driving voltages by the optimized of device structure, which is strongly affected by charge transport balance. With a model small molecule-polymer hybrid system, time-of-flight and transient electroluminescent measurements were performed to study the balanced charge transport and its role for device performance. Analysis of time-of-flight measurement shows that amorphous hole transporting materials mixed with light emitting polymer increases the mobility, with transition from nondispersive to dispersive transport induced by the charge trapping effect. In the case of doped electrol phosphorescent system, dopant can also act as a trapping site. A strong correlation between the position of activation energy and characteristic time can be observed by electrochemical measurements performed on charge transport and exciton diffusion. Graded concentration profile was formed not only by the doping control but also by the laser thermal transfer method. Improved device performance and its analysis with positional exciton formation control were presented. Such a device optimization method must be an essential technique for designing better OLED structure of large-sized and flexible electronics.

**110.6** Oriented growth of anthracene and pentacene thin films. Hua Zhou1, Lan Zhou1, Brian Wang2, Ricardo Ruiz2, Alex C Mayer2, Alexander George O Malliaras2 and Randall L Headrick1

1Department of Physics and Materials Science Program, University of Vermont, Burlington, Vermont; 2Department of Materials Science and Engineering, Cornell University, Ithaca, New York; 3Cornell High Energy Synchrotron Source, Cornell University, Ithaca, New York.

Azimuthally oriented anthracene thin films were grown by a new process, with domain sizes in the centimeter range. The morphology consists of parallel, oriented row like structures, which have identical crystallographic orientations. This is in contrast to films grown by conventional techniques that are oriented with (DOL) planes parallel to the surface, but are composed of grains with random azimuthal orientations. Depending on the exact growth conditions, fine filaments, micron-wide rows, or fully continuous films are formed. Synchrotron x-ray diffraction studies confirm that the films are highly ordered and oriented. Pentacene epitaxial growth by vapor deposition atop oriented anthracene was studied using in-situ synchrotron x-ray scattering. Pentacene layers are found to be highly oriented. This represents true epitaxial growth in an organic thin film system. Epitaxial organic heterostructures have the potential to produce materials and devices with improved properties and performance. Electrical transport measurements of films fabricated by these methods are underway.

**110.7** Growth and Electrical Properties of Pentacene Ultra-thin Films. Ricardo Ruiz2, Alex C Mayer2, George G Malliaras2, Randall L Headrick3, Alexander Kazimirov4 and James R. Kriegsmann5


Understanding charge transport in organic/manganic and organic/organic interfaces is crucial for the development of flexible electronics. Charge transport in pentacene thin film transistors is believed to occur in the first few monolayers adjacent to the gate substrate. However, a complete study that relates film thickness and morphology to transport mechanisms is still missing. In an attempt to address this problem, pentacene films were evaporated onto silicon oxide and onto polyethyleneimithacrylate (PMMMA) substrates. Film morphology and crystal structure were analyzed by atomic force microscopy and synchrotron X-ray radiation. Top-contact thin film effect transistors fabricated with these films were used to evaluate the electrical properties and the field effect mobility as a function of film thickness.

**110.8** Electrical Hysteresis of PEDOT/PSS-Metal Contact Devices. Shengchun Liu, Yi Su and Kody Vurahraman; Institute for Micromanufacturing, Louisiana Tech University, Ruston, Louisiana.

Poly(ethylene dioxythiphene) doped with poly(styrene sulfonate) or PEDOT/PSS is an air-stable, solution processable p-type semiconductor polymer. Recently, it has been intensively studied for electronic applications. Since the semiconductor-metal contacts are very important for device fabrication, we investigated the electrical properties of PEDOT/PSS-Au as a test device. It is probably the first time that such a device is found to have an abnormal 'hysteresis' in its electrical characteristics. AI-PEDOT/PSS was reported to be a Schottky contact and the work function of PEDOT/PSS and that of gold are very close. Thus the AI-PEDOT/PSS-Au device is supposed to be a Schottky diode. However, our results reveal that the device exhibits unexpected abnormal electrical properties. First, the 'forward' bias curve occurs within the device is presumably 'reverse' biased. Secondly, the 'turn-on' voltage of the I-V curve increases during the following repeated measures when the voltage at Al is sweeping from negative to positive (Au is always grounded) and finally becomes stable at 3 4 V. This 'turn-on' voltage can be partially recovered or reduced with time or by exerting an opposite sweep. The device exhibits 'hysteresis' in its multiple current-voltage characteristics and quasi-static capacitance-voltage characteristics. An MIS structure at the Al-PEDOT/PSS interface by reaction between the dopant poly(styrene sulfonate), is believed to be responsible for the rectification behavior of the device. A model in terms of ion motion and charge storage is proposed to explain the above hysteresis phenomenon. The authors believe that both the polaron and ions (e.g. H+) contribute to the electrical conduction of PEDOT/PSS. When a positive voltage is applied to the aluminum electrode, H+ ions are pushed to the Al-PEDOT/PSS interface, leaving a depleted and negatively charged region behind. An internal electrical field (i.e. additional potential barrier) forms in this manner. Therefore, larger voltage is needed to turn on the device during the following measurement. In the mean time, an electrical process may happen at the PEDOT/PSS-Au interface—the H+ may get electrons and produce H atoms. With time some H+ ions can slowly diffuse back to the depleted region such that the internal electrical field can be reduced. Opposite of external field is applied such process may not but cannot recover the original state because some H+ ions become H atoms. This case is similar for other cations like Na+.

**110.9** White Electroluminescent Devices using Blue and Red Light-Emitting Conjugated Polymer Blends. Do-Hoon Hwang1, Moo-Jin Park1, Suk-Kyung Kim2, Changhee Lee2, Yong-Bae Kim3 and Hong-Ku Shim1

1Applied Chemistry, Kumoh National Institute of Technology, KumK, South Korea; 2Department of Chemistry, Incheon National University, Incheon, South Korea; 3Liquid Crystal Research Center, Department of Chemistry, Kon-Kuk University, Seoul, South Korea; 4Center for Advanced Functional Polymers, Department of Chemistry and School of Molecular Science (BK21), Korea Advanced Institute of Science and Technology, Taejon, South Korea.

White EL devices attract much attention because these applications include full color displays using color filters as well as LCD back light applications. Several approaches have been done to obtain white LEDs. The doping method has been widely used to obtain white light. For small molecule device, red emitting material is co-deposited with blue and/or green emitting materials. The doping method has been widely used to obtain white light. For small molecule device, red emitting material is co-deposited with blue and/or green emitting materials. In solution processed polymer devices, it is reported that blends of blue (e.g. 1T-Pe, C60), and yellow (e.g. PFSS, polyfluorene) emit white light. In this study, white light-emitting devices were fabricated using blends of a blue light-emitting polyfluorene copolymer and a red emitting PPV derivative. Efficient energy transfers between the blue and red light-emitting polymer, which was observed in PL spectra of the blend films, provides a good advantage to get a white light emission due to better blend ratio controllability. The EL devices were fabricated and white light-emission was obtained for a certain blend ratio.

**110.10** Synthesis and transistor performance of tetracene derivatives. Hyunsik Moon1, Evert-Jan Borkent4, Andrew J. Lovinger1 and Zhehan Bao3

1Department of Physics and Materials Science Program, University of Michigan, Ann Arbor, Michigan; 2Bell Laboratories, Lucent Technologies, Murray Hill, New Jersey; 3Macromolecular Science and Engineering, University of Michigan, Ann Arbor, Michigan.

Over the past decade, remarkable progress has been made on the performances of organic thin film transistors (OTFTs), which are essentially governed by both microscopic, single-molecular structure and macroscopic organization in thin film. To improve device performance, it is desirable to understand various aspects including molecular properties, film-forming characteristics, role of solid-state film morphology and device stability. Up to date, polycyanes, such as tetracene and pentacene, and oligothiophene derivatives have been intensively studied, showing high mobilities and on/off ratios. However, only few polycyan derivatives have been reported because of the difficulty in incorporating functional groups into polycyanes. In this work, we prepared halogenated and alkyl-substituted tetracene.
derivatives, investigated the change in their solid state packing by specific tailoring of functional group substitution, and studied its effect on charge transport properties and device performance. Transmission electron microscopy demonstrated that mono-substituted derivatives (5-bromo or 5-chloro tetracenes) had platelet-shape single crystals and di-substituted derivatives (5,11-dichloro tetracene) needle-shaped single crystals. Based on preliminary data of crystal structures, dichlorotetracene has a π-π stacking motif, which, in principle, facilitates better carrier transport. Substitution of an electron withdrawing group is expected to alter the nitrogen atmosphere of the molecule as well as the electronic properties, which will affect the packing mode and density. In this presentation, we discuss the effect of the bromo, chloro, and methyl functional groups on molecular properties, thin-film morphology, and charge transport, and establish structure-property relationships in the tetracene derivatives.


10.11 Abstract Withdrawn

10.12 Organic Thin Film Transistors based on Electron Donor-Acceptor-Donor Type Co-oligomer with π-stacked Structure, Weon Yang Jang1, Hyunnam Moon2 and M David Curtis1,2. 1Chemistry, University of Michigan, Ann Arbor, Michigan; 2Macromolecular Science and Engineering Center, University of Michigan, Ann Arbor, Michigan.

Recently, Organic conjugated materials have been studied very intensively as active materials for organic thin film transistors (OTFTs). The unique properties of these materials make them more attractive than inorganic semiconductors applications requiring larger area coverage and flexibility. Understanding and predicting the performance of OTFTs, early work has been limited to a few kinds of conjugated materials, such as thiophene oligomers, polythiophene, and pentacene, etc. However, most of these materials are packed in the so-called herringbone pattern, in which the molecules are arranged in a face-to-edge structure, and π-π contacts are minimized. Our group has published the synthesis and characterization of several kinds of π-stacked oligomers and co-oligomers. These π-stacked oligomers may facilitate carrier transport by decreasing the hopping barrier between neighbor molecules through their face-to-face structure.1 In order to understand their electrical properties, such as carrier mobility, we report the synthesis, characterization, and transistor properties of 5,5-(4,4-dibutyldithieno[3,2-b:2',3'-b]thiophene-5,5')/(3,4,5-tris(2-ethylhexyl-5)-2,2-dithienyl (BT2B). BT2B has a π-stacked structure in which donor-acceptor-donor groups in the molecule are alternately distributed. Stille coupling reactions were used to prepare this compound. The solid-state structure of BT2B features a short intermolecular distance of 3.5 Å. In thin films, the π-stacks are parallel to the film substrate as determined by X-ray diffraction. The carrier transport in thin films of co-oligomers, characterized by space-charge-limited current (SCLC) spectroscopy and field effect mobility, will be discussed.

10.13 An original flexible structure for Organic Photovoltaic Devices, Ornella Sanna1,2, Piero Cosseddu1, Mario Cesu1 and Annalisa Bonfiglio1,2. 1Dept. of Electrical and Electronic Engineering and INFN, University of Cagliari, Cagliari, Italy; 2Centre S3 - INFN, National Institute of Physics of Matter, Modena, Italy.

A simple idea is proposed for the realization of organic photovoltaic devices on flexible substrates. According to this, a transparent layer, a few micrometers thick and completely flexible, works as mechanical support. It is an insulting material, which has good mechanical and electrical properties and, most important, it is completely transparent to ultraviolet light. For this reason it could be suitable for being used as transparent protective layer for large area photovoltaic devices. Starting from this flexible, transparent layer an organic semiconductor is sandwiched between the two electrodes, being one of them transparent. Different organic semiconductors, deposited both by spin-coating and by thermal evaporation, have been used in order to test the device behaviour. The quality of semiconductor layers has been tested by Atomic Force Microscopy which has shown a good coverage of the transparent electrode by the organic semiconductors. In spite of the transparent characteristic of the SiO2 layer and the atmosphere, no protection from oxygen), the dark I-V characteristics are in agreement with the results already reported in literature for the employed organic materials. A comparison between dark and light measurements has been made, reporting the absence of light sensitivity with respect to the photocurrent. Due to the extreme mechanical flexibility of these structure, it could be possible to build working devices, able to be transferred on unusual substrates as, for example, textiles or 3D surfaces, paving the way to very innovative applications. Work is in progress in this direction.


Nanocrystalline silicon is a candidate material for fabricating high mobility devices on plastic substrates. A major issue in the processing of nanocrystalline silicon thin film transistors (nc-Si:H TFTs) at ultralow temperatures is the size of the SiO2 gate dielectric. This is a generic problem because all ultralow temperature, plastic compatible, TFT technologies battle instabilities and leakage of the gate insulator. SiO2 deposited at less than 250°C by radio frequency plasma enhanced chemical vapor deposition (PECVD) typically exhibits high drift and leakage currents. Secondary ion mass spectrometry measurements show that the hydrogen concentration in PECVD oxide deposited at 150°C on nc-Si:H is 0.8 at.%. This is much higher than in thermal oxides on crystalline silicon substrates which display concentrations of less than 0.003 at.% The leakage currents for thermal oxides on Si at a bias of 5V are 2x10^-9 A/cm² whereas for 250°C PECVD oxides on nc-Si:H the currents are 1x10^-7 A/cm². As the temperature of the SiO2 deposition is reduced to 150°C these current values degrade by up to two orders of magnitude. The hydrogen content which may cause drift currents across the PECVD oxide originates from the nc-Si:H substrate and the silane source gas. We analyzed the 800nm gate oxide in capacitor structures of Si / SiO2 / n+ nc-Si:H / Cr / glass and Al / SiO2 / s-Si. Vacuum annealing the nc-Si:H prior to PECVD of the oxide allows hydrogen to effuse from the nc-Si:H film and reduces the amount of hydrogen incorporated into the oxide that is deposited on top. SiO2 deposited at 300°C from silane and nitrous oxide at high helium dilution has a still greater effect on lowering the hydrogen content. The leakage currents at a 5V bias dropped from 1x10^-7 A/cm² to about 5x10^-9 A/cm² using helium dilution and the vacuum anneal procedure which lowered the current by an additional factor of two. Thus we observe that both the nc-Si:H anneal and the SiO2 deposition at high helium dilution lessen the oxide leakage current.

10.15 Electrical and optical investigations on ion implanted polycarbonate, Jae Hyung Lee and Doo Jeong Yang, Korea Atomic Energy Research Institute(KAERI), Taejon, South Korea.

Polycarbonates(PC) were implanted with N+, Ar+, Kr+, Xe+ ions at the ion energy of 20 50keV, and the dose rates of 5x10¹ⁱ 7x10¹⁸ ions/cm². The relationship between the electrical and optical properties of an ion implanted PC was investigated by means of the UV-Vis and Fourier transform infrared spectroscopy(FT-IR) and Surface resistance measurements. The electrical conductivities, which depend not only on the ion dose but also the incident energy, were found to have a relationship to the optical absorption. Optical absorption provides information regarding the optically induced transitions and the variations in the energy band gap after ion beam implantation. The ion implantation leads to the formation of free charge carriers, which indicates a lowering of the energy band gap. The decrease of the energy band gap, which implies an increase of the conductivity of the ion beam irradiated polymers, can be explained by the formations of carbon network and conjugated double bonds. After ion beam irradiation, the transmittance in the UV-A(320 400nm) range decreases from 88 to 2% and the surface resistance decreases in the order of 10⁶Ω.

10.16 C(U)-investigations on organic MOS-structures. Georg Jakopic, Heimut Schroen, Bernhard Lamprecht, Barbara Stadlober and Guenther Leising, Joanneum Research, Weiz, Austria.

The analysis of the behaviour of MOS-like structures of organic semiconductor devices can provide useful information about intrinsic properties of the semiconductors as well as of the dielectric material. Depending on the sign and the value of the bias voltage, information about the dielectric constant, substrate (semiconductor) doping, the presence of majority carriers, carrier density, and chemically pure interfaces is of vital importance. We have investigated C(U)-investigations on different organic semiconductors and we present results on the influence of different parameters. If dealing with thin film of small molecules grown by thermal evaporation, growth parameters like average and initial evaporation rate, substrate temperature, substrate precleaning, residual gas composition in the
vacuum chamber play a significant role for the microscopic layer formation and consequently for the semiconductor properties as well as for the relationship of an organic semiconductor to the deposition of the dielectric layer not only determine the dielectric properties but also the interface between dielectric and semiconductor (an important influence have e.g. solvent residuals and their possible diffusion into the semiconductor layer with subsequent degradation acceleration). Last but not least illumination studies have been performed and related to intrinsic trap filling and carrier release processes.

**10.17 Photosensitive Carbazoleylethynylmethacrylate Copolymers on Flexible Substrate for Optical Information Registration.** Stefan Robu1, Igor Dementiev2 and Serghei Duminic1, 1Department of Chemistry, University State University, Chisinau, Moldova, 2Industrial and Environmental Chemistry, Moldova State University, Chisinau, Moldova. This report presents results of study of some organic materials suitable for creation of photothermal media on (flexible) base for optical information recording. In particular, speech is about donor-acceptor systems on the base of carbazol containing polymers, in particular, carbazoleylethynylmethacrylates (CEM) with acetylidencylamethy (OMA) and polyoxypropylcarbazol (PENC) copolymers sensitization which was made by means of 5-20% of trinitrofluorenone (TNF), N-phenylnimo-2,4,7-trinitrofluorenone (NFN) and ditionomethylen-2,4,7-trinitrofluorenone (DTF) (containing donor-acceptor groups) and additives of photochromical substances of indolyniospirobenzospyran series. There were studied the dependencies of photoreception to the electron mobility under light intensity and temperature of heating of polymeric material and also the spectral dispersion of photosensitivity. It was established that maximum of photosensitivity is observed at the concentration of sensibilizing agent 12-14%. Heating above 60°C leads to sharp decrease of photosensitivity of developed organic materials. It was established that donor-acceptor systems as photoplastic (PP) layers possess photosensitivity on the level 1-8-10^-4 J/cm^2. The introduction of PP layers of 6-10% photocromium additives leads to 2-3 times increasing of the photosensitivity of the given donor-acceptor system. At that the essential growth of photosensitivity is observed in the blue-green part of visible spectrum. Also, it was established that 8-nitro-3,4-methinindolyniospirobenzospyran possesses the greatest effect of sensitization. The fact that adsorption band (500-600 nm) in the visible part of spectrum confirms the amplification of concentration of donor-acceptor groups in PP layers and, as result, considerable growth of photosensitivity. The received results are discussed. Thus, donor-acceptor systems, developed on the base of copolymer CEM-OMA, demonstrate photosensitivity of 10-8 J/cm^2 at 80-88°C at 2.3 times higher than in case of usual donor-acceptor systems. Acknowledgments: This work has been supported by CRDF Grant ME2-2317-CH-02

**10.18 Charge trapping and scattering by extrinsic gas dopants in Alq3:** K.K. Sa and H.H. Fong, Department of Physics, Hong Kong Baptist University, Hong Kong, Hong Kong.

The effects of various ambient gases (N2, O2, H2O) to the electron mobility of tris(8-hydroxyquinolimine) aluminum, Alq3, were examined. For clean Alq3, the electron transport is non-dispersive and essentially trap-free as revealed by optical time-of-flight measurements. At 296K, the electron mobility (µe) spans the range 0.2-1×10^-6 cm^2 V^-1 s^-1 when the field varies from 0.4-9.0 MV cm^-1. Exposing pristine Alq3 to moisture of dosages in the range 1-100 Torr s^-1 causes a gradual reduction in µe by a factor of 4. In contrast, exposing to same dosages of oxygen does not cause any noticeable changes in µe. The effect of oxygen on µe can be observed only at much higher oxygen dosages (>105 Torr s^-1). It is proposed that H2O diffuses into Alq3 during exposure and subsequently forms large scattering centers for excited electrons. On the other hand, oxygen induces charge traps at high dosages. Moisture control appears to be the most critical factor for the long-term operation of Alq3-based organic light-emitting diodes.

**10.19 Organic Thin-Film Transistors Developed by Alignment-Free Inkjet Printing Technique. Masaaki Ando1,2, Hiroshi Susuki3,4, Masahisa Kawasaki3,4, Shinji Imazeki1,2 and Tooshide Kamata1, 1Opto-electronic Industry and Technology Development Association(OITDA), Tsukuba-city, Ibaraki, Japan; 2Advanced Research Laboratory, Hitachi, Ltd., Hitachity-city, Ibaraki, Japan; 3Hitachi Research Laboratory, Hitachi, Ltd., Hitachity-city, Ibaraki, Japan; 4National Institute of Advanced Industrial Science and Technology, Tsukuba-city, Japan.

Alignment of the device components in a Thin Film Transistor (TFT) is one of the most important factors for the preparation of an organic TFT with high performance. Especially, it is very serious problem for the microsystem of an organic TFT on a flexible substrate by employing this fabrication technique. Because the flexible substrate often shows deformation during the device preparation, which causes the misalignment of each device components, leading to the degradation of the TFT performance. In this study, we have developed a novel alignment-free fabrication process of printable electrodes for organic TFTs. This process provides accurate definition of the device components without increasing process complexity, where solution-processed source/drain electrodes are self-aligned to a gate electrode by using self-assembly monolayer (SAM) optically patterned by back substrate exposure technique. After stripe patterns of gate electrodes were formed on glass substrates, transparent SiO2 film was deposited. Hydrophilic SAM was deposited and the substrate was irradiated from the opposite side of the gate electrodes with UV light. The UV-exposed areas unshadowed with the gate electrodes were transformed from hydrophobic to hydrophilic. Source and drain electrodes were fabricated by printing water-based Ag nanoparticle on the hydrophilic areas interposed between the hydrophobic strips above the gate electrodes using a micro-pipette and baking in vacuum. We confirmed that organic TFTs with channel length of 2.5cm can be made by employing this patterning technique. The channel length was completely restricted by the hydrophobic stripes just above the gate regions. In this study, we fabricated pentacene TFTs by using this novel process and examined its TFT performance. Pentacene layer was deposited by thermal evaporation. The field effect mobility, threshold voltage and on/off current ratio for the pentacene TFT fabricated through the above process were estimated to be 0.16/72/10 and 10, respectively. The obtained field effect mobility was about two times larger than that of the case without the SAM treatment. This mobility improvement is mainly due to the large grain size of pentacene in the film processed by our newly developed method. This shows that the coated SAM layer for the alignment-free electrode fabrication also contributes to self-assembly of the deposited pentacene and improvement of the film quality. This alignment-free process for source/drain electrodes will give us a clue to a novel fabrication process for high-definable printable organic TFTs. A part of this work belongs to “Advanced Organic Device Project” under contract between OITDA and NEDO.

**10.20 Conducting Polyppyrrole-based Field Effect Transistors fabricated by Spin Coating and Inkjet Printing. Fengliang Xue, YI Su and Kody Varahramyan, Institute for Micromanufacturing, Louisiana tech university, Ruston, Louisiana.

Polyppyrrole (PPy) is one of the most widely used conducting polymers due to easy processing and good stability. Heavily doped polyppyrrole has been used for chemical gas sensors, biosensors, and source/drain/gate electrodes [1-2]. Recently it has been mentioned demonstrating high field effect effect behavior in transistor applications, but no experimental reports containing MISFET characteristics were reported [3-4]. In this paper, we present highly conducting PPy polymer as a semiconductor material for field effect transistors application. Our experimental results show such conducting polymer is promising for flexible polymer electronics. Both inkjet deposition and spin coating were used for deposition of PPy polymer for comparison of transistor’s performance. Heavily doped n-type silicon was used as a starting material. Then, 2200 Å thermal oxide is grown as gate dielectric. Finally, conducting PPy polymer was spin coated, and metal Al was thermally evaporated using a shadow mask to form source and drain electrodes. The silicon substrate was used as gate electrode after thermal oxide was stripped away on the backside of the wafer. When inkjet printing was used, metal Al was first deposited to form source and drain electrodes, then conducting PPy polymer was printed in channel region using a drop-on-demand inkjet printer. Fabrication and electrical characterization of the devices were performed in ambient environment.Keithley electric parameter probe was used for the experimental characterization. The experimental results show that source/drain channel contact is Schottky contact, which is preferred for low leakage current, because such a highly conducting polymer transistor is normally-on. Positive gate voltage is required to depleting the channel in order to switch the device off. From measured Id-Vd curves, we obtained that the switch-off voltage was around 25 Volt, the saturation mobility was 0.022 cm^2/v·s, and the on-off current ratio was about 100. The drain current of the fabricated device was 0.004 cm^2/v·s. The experimental results show that device performance from inkjet printed PPy polymer transistor is not as good as that of the spin coated transistor. It is possibly due to inkjet printed dot and line quality and surface roughness. Further research work is still going on this kind of polymer transistors. References 1. K. Potje-Kamthol, Critical Reviews in Analytical Chemistry, 32(2),121-140,2002 2. T. Cui, G. Liang, and K. Varahramyan, IEEE Transactions On Electron Devices, 50(5), 1419-1422, 2003 3. A.J. Epstein, P. M. Lee, S. C. Smith, and V.N.Prigodin, Synthetic Metals, 137,850-861,2003.
and epitaxial thin films under different growth conditions and investigated them by atomic force, scanning electron and polarization microscopy. The aim was to identify the critical growth parameters with respect to surface quality, thickness and crystallinity of the crystals and with respect to homogeneity, size and shape of grains, ordering, substrate dependence, morphology and phase formation of the polycrystalline thin films. The polymeric phase is stabilized and the macrostructure of crystals and films were determined by X-ray diffraction, whereas micro-structural differences, small impurity concentrations and the temperature dependence of the structure were investigated by Raman microspectroscopy. It turned out, that the growth process, the film quality and/or the phase formation are highly sensitive to the deposition rate, the choice of the substrate material, the substrate temperature, the film thickness and the purity of the source material. We observed a clear power-law dependence between deposition rate and grain size. In order to draw a bow between the structural and the electronic properties of pentacene, thin film transistors were fabricated on the different polymeric phases and different dielectric and electrode materials. The carrier transport properties of pentacene single crystals were investigated by space charge limited current measurements as well as by time of flight measurements. It turned out, that the transistor characteristics are strongly correlated with the morphological as well as with the structural parameters of the active layer, with the integrity and the dielectric properties of the insulator and with the contact resistance characteristics of the electronic contact. 

SESSION 111: Poster Session: Flexible Materials and Electronic Devices

Chair: Babu Chalamala
Thursday Evening, April 15, 2004
8:00 PM
Salons 8-9 (Marriott)


In order to create new building blocks for organic transistors, several new derivatives of pentacene and tetracene have been synthesized. Their assembly and electrical response in thin film have been studied. Dihydrodiazapentacene have the same molecular shape as pentacene but are much easier to prepare and have much greater environmental stability. Thin films made from the dihydrodiazapentacene behave as field effect transistors with mobilities and on/off ratios high enough to be useful in certain applications. Some of the derivatives synthesized for this study have unexpectedly high solubility in polar solvents such as DME and DMSO. The crystal structure from DME reveals self-assembled channels with each of the aniline functionalities forming a hydrogen bond with solvent. In more non-polar solvents, the solid-state assembly switches to a herringbone motif characteristic of the linear acenes. 6, 13-diazapentacene forms vacuum-evaporated films, which are highly ordered polycrystalline and have unique morphology and conductivity up to $10^{-2} \Omega^{-1} \cdot \text{cm}^{-1}$. Its crystal structure indicates that 6, 13-diazapentacene molecules stack co-facially with each other rather than in a herringbone motif. Obviously several derivatives of tetracene have also been synthesized to control the packing mode and to enhance the contact between molecules and the substrate.

111.2 Growth Process Control of Polymorphic Thin Films and Single Crystals for the Adjustment of Structural and Electronic Properties of Pentacene. Baoguo Stadler, Hannes Mareshl, 1Valentin Satzinger, 1Heinz Pickelh, 1Helmut Schoen, 2Anja Haase, 1Werner Rom, 3Georg Jakopic, 1Dieter Somitsch, 1Reinhard Kaindl, 1Josef Kalcher, 1Institute of Nanostructured Materials and Photonics, Research, Graz, Austria, 2Institute of Experimental Physics, Karl-Franzens University, Graz, Austria, 3Institute of Mineralogy and Petrology, Karl-Franzens University, Graz, Austria, 4Institute of Chemistry, Karl-Franzens University, Graz, Austria.

Due to its outstanding carrier transport capabilities pentacene is a prominent candidate for the active semiconducting layer in organic thin film transistors. This compound crystallizes in a layered structure with herringbone arrangement within each layer. Pentacene appears in several polymorphic structures, which differ basically by their c-axis lengths, meaning that the angle at which the molecules adsorb relative to the substrate changes from phase to phase. Obviously the interaction of the π-electron systems between adjacent molecules depends strongly on the stacking nature of the molecules. It has been argued, that a smaller angle between the molecular axis and the surface normal results in a larger orbital overlap which is expected to give better carrier transport properties. Therefore it is of major interest to clarify and control the growth conditions for the different phases. We have synthesized high-quality pentacene single crystals...
4-phenyle vinylene) (MEH-PPV), is widely used as an Electro luminescent Polymer for the fabrication of PLEDs. The degradation of MEH-PPV is a major factor in short lifetime and low efficiency of PLED. Deep Level Transient Spectroscopy (DLTS) and Thermally Stimulated Current (TSC) are usually used for studying the polymer degradation. In this paper we present a different way to investigate degradation of MEH-PPV using Reflection IR Spectroscopy. Our experimental results of a different way of characterization of the polymer layer was obtained by optical methods. We report the effect of aging on the polymer layer with aging which indicates the formation of carbonyl peak at 1651 cm$^{-1}$ with aging which indicates the presence of oxygen. These results are consistent with other researchers. High frequency C-V curve of the MIS (Al/MEH-PPV/p-Si) capacitor shows 0.35% increase in capacitance after aging which indicates no increase in thickness of the polymer layer assuming minimal dielectric constant change. This increase in thickness suggests the absorption of moisture thus forming volatile components which causes the polymer layer to swell. High resolution microscopy images show the swelling of the polymer layer which causes the metal layer on top of polymer to swell and ultimately burst within 48 hrs. In our quasi-static C-V measurement we found extension of the weak inversion region in the form of platform before strong inversion. This suggests that the minority carriers from the p-Si start recombining with the holes in the MEH-PPV polymer layer. This platform extends until the minority carriers recombine. After recombination of the minority carriers, the quasi-static C-V curve follows the strong inversion. With aging, further extension of the platform in the weak inversion region is observed. Other researchers have shown that the molecular oxygen serves as a trap in the MEH-PPV layer which attaches with an electron to form negative ion ${{\text{O}}_2}^-$. This n-type carrier trap. Extension of this platform in the weak inversion region with aging can be explained due to more hole-electron recombination in MEH-PPV layer. The oxygen combines with electron to form negative ions which recombines with the holes of the MEH-PPV polymer. In this case it takes more time for carrier recombination and thus causing more extension. Thus both the C-V analysis and Attenuated Total Reflection IR Spectroscopy are two powerful tools for investigating degradation of polymer materials for improving reliability of PLEDs.

11.4 Tetrahedra from Aryleneethynylenes - From Small Molecules to Luminous Glasses, Heiner Detert, Institut fuer Organische Chemie, Johannes Gutenberg-Universität, Mainz, Germany.

Sthelene oligomers exhibit efficient photo- and electroluminescence in the blue to yellow region but the application of these low molecular weight materials is limited by their strong tendency towards crystallisation. OPV's as side chains or in the main chain of a polymer or dispersed in polymeric matrices are suitable ways to overcome this limitation, an alternative is opened by globular molecules. This poster presents the synthesis of silanes and methanes with four alkoxy-substituted stilbenoid chromophores connected to the central atom, thus giving rise to molecules a tetrahedral shape. These molecules with monodisperse conjugated segments form amorphous films, in the solid state, the absorption spectra are shifted to the red whereas the fluorescence is not affected by aggregation. The film forming capability depending on the lengths of the conjugated segments and the flexible side chains.

11.7 Fabrication and Photoelectrical Characteristics of Polymer-Organic Blend Photodetector, Difei Qi, Sandra Selmic and Kody Varahramyan; Institute for Micromanufacturing, Electrical Engineering Program, Louisiana Tech University, Ruston, Louisiana.

Polymer optoelectronics and microelectronics have been recognized as next generation technologies. Among the widely investigated materials for photodiode, LED and solar cell applications is the insoluble conjugated semi-conjugated polymers (SCC). One polyfluorene which is the most efficient in this paper, we present experimental results of a blended polymer-organic compound photodiode. This diode is based on a soluble derivative of PPV, poly(2-methoxy-5-(2-ethyl-hexyloxy)-1,4-phenylene vinylene) or MEH-PPV; and the organic material ethyl viologen dibromide or EVD. Possible applications of this polymer/organic blend photodiodes are imaging systems, large sensor systems and optical networks. The MEH-PPV acts as an electron donor with a relatively low quantum efficiency (0.07%) [1] due to a limited exciton diffusion length, molecular structure distortion, and low hole mobility. The EVD acts as an excellent electron acceptor, therefore we predict that it will significantly increase the photoconductivity of a pristine MEH-PPV film. In making photodiodes, some MEH-PPV were spin-coated on indium tin oxide coated glass substrates. The thickness of these polymer-organic thin films were approximately 130nm. An aluminum cathode was thermally evaporated. These devices were illuminated under a monochromatic light in UV and visible range wavelengths. These thin polymer-organic blend photodiodes have shown a ten-fold increase in responsivity and quantum efficiency compared to pure MEH-PPV photodiode devices. The increase in photoconductivity of blended MEH-PPV:EVD photodiodes may be due to ultra fast charge transfer by EVD$^+$. The results from this work clearly demonstrate the application of the reported approach for the fabrication of photodiodes with increased photoconductivity characteristics. Reference [1] J. Pettrich and R. H. Friend, "Ultrathin Organic Photovoltaic Devices," Synthetic Metals, vol.102, p. 976, 1998.

11.8 Photolithographic Micropatterning of an Electroluminescent Polymer Using Photobase Generator. Lee Sang Kyun1, Jung Byung-Jun2, Ahn Taek2 and Shin Hong-Ku1; 1Electronic Materials Lab, Samsung Advanced Institute of Science and Technology, Yoido, Yonsei, South Korea, 2Chemistry, Korea Advanced Institute of Science and Technology, Daejeon, ChungCheong, South Korea.

Recently, much attention has especially been focused on the techniques of photopatterning for conjugated polymer by introducing the chemical amplified photolithographic (CAP) method which is used in conventional manufacturing methods for the integrated circuit (IC) chip. This technology uses the application of generating acid upon photolysis and solubility change between exposed area and unexposed area. Renak et al reported the patterning of poly-(p-phenylenevinylene)(PPV) derivatives by using a photonic acid generator (PAG) in elimination reactions upon the irradiation through a photomask. In the present work, we report a new photolithographic micropatterning method for conjugated polymer using halogen precipitator conjugated polymer and photobase generator (PBG) and its application for polymer LEDs. The methods of PPV synthesis were published abundantly in previous literature. Especially, the Gilch route is a prevalent method using excess strong base because of simplicity without thermal elimination step and relatively rare side reactions. But if base less than one equivalent is used, an organic soluble haloprecursor polymer is obtained, and then it can be converted into the fully conjugated polymer by thermal elimination. o-Nitrobenzyl carbamate derivatives such as PBG are well known to generate the base upon the photolysis reaction, which is photolytically converted of carbamate derivatives to amine upon irradiation with UV light below 400 nm. Consequently, the generated amine renders the haloprecursor PPV to conjugated PPV by base catalyzed dehydrohalogenation reaction (E2 elimination).

SESSION 112: Materials and Processes for Flexible Electronics II

Chair: Arolida Nathan
Room 2018 (Moscone West)
Friday Morning, April 16, 2004
Room 2018 (Moscone West)

Polyfluorenes are a class of polyaromatic macromolecules that are characterized by a conjugated backbone structure that consists of 9,9-dialkylfluorene units in combination with units of another aromatic group. These materials have been designed to perform as the organic semiconductor layer in polymeric field effect transistors (PFETs). One polyfluorene that has received a great deal of attention in recent years is poly(9,9-diocytfluorene-alt-bithiophene) or "F8T2". F8T2 has charge mobilities as high as 0.02 cm$^2$/V_s with current on/off ratios of up to 10$^6$. F8T2 is also more resistant to doping by photoconductive oxygen than other polysemiconductors and has good solubility in solvents such as mestyleine. This favorable solubility has allowed the preparation of inks for use in various printing applications. While F8T2 is also more resistant to doping by photoconductive oxygen than other polysemiconductors and has good solubility in solvents such as mestyleine. This favorable solubility has allowed the preparation of inks for use in various printing applications. While F8T2 is also more resistant to doping by photoconductive oxygen than other polysemiconductors and has good solubility in solvents such as mestyleine. This favorable solubility has allowed the preparation of inks for use in various printing applications. While F8T2 is also more resistant to doping by photoconductive oxygen than other polysemiconductors and has good solubility in solvents such as mestyleine. This favorable solubility has allowed the preparation of inks for use in various printing applications. While F8T2 is also more resistant to doping by photoconductive oxygen than other polysemiconductors and has good solubility in solvents such as mestyleine. This favorable solubility has allowed the preparation of inks for use in various printing applications.
Organic semiconductors exhibiting complementary n-type carrier mobility are the key components for the development of the field of plastic electronics. We present here a novel series of oligothiophenes designed to improve performance and stability under electronic-traafic conditions. Furthermore, the key structural features of these compounds allow additional modifications of the n-type conducting core to achieve material solubility and processability. Thin-film transistor (TFT) devices were fabricated employing both vacuum- and solution-deposited semiconducting layers. Field-effect transistor measurements indicate that all the members of this new series are n-type semiconductors with mobilities of 18(18) /5(7) cm2/Vs and 18(7) cm2/Vs, respectively. Specifically, this represents a key milestone in the design, understanding, and development of the next generation of highly efficient n-type OTFT components.


One of the main attractions of organic semiconductor materials is the potential for low-cost solution-based processing. However, organic thin film transistors (TFTs) that have exhibited the highest field-effect mobilities have thus far tended to be fabricated with evaporated small molecules with limited solubility. Here we report on OTFTs made from a novel thiophene-based oligomer. The functionalized oligomer is soluble in organic solvents, but becomes insoluble when thermolysis takes place under growth conditions which cause the thiophene molecules reorganized into highly crystalline films. Crystallinité was characterized by x-ray diffraction and atomic force imaging, the latter of which depicted the nucleation of molecular terraces. The formation and overall height of terraces was observed to be dependent upon the thermolyzing temperature, the surface energy of the substrate, and the purity of the material, and was correlated to overall performance. For both dip-cast and spin-cast samples, devices were fabricated at a process temperature of 180°C with mobilities of 0.05 cm2/Vs and on/off ratios > 105. The devices were relatively stable in both air and common solvents, degrading by 25% in mobility even when immersed from the solvents from which they were initially cast. The solubility characteristics and process temperatures for these devices may be particularly suitable for solution processing on flexible substrates.

10:30 AM *112.5
Polymer Electrodes for Flexible Organic Optoelectronic Devices, Woohong H. Kim, Leonidas C. Palilis, Antti J. Makinen, and Mario Leclerc. With ongoing improvements in the performance of small molecular organic thin film transistors (OTFT) and the first demonstrations of integration and circuit fabrication, the use of OTFTs as semiconducting layers in hybrid solar cells is becoming a reality for the future. The use of solution-processed organic electrodes will also be needed, as these can be integrated on a wide variety of flexible substrates. We have thus fabricated and characterized organic light emitting diodes (MOLEDs) using these polymers as anodes.

Ultraviolet photomission studies have shown that the hole injection barrier between these polymer anodes and common organic hole transporters is in the order of 0.5 eV, comparable for ITO electrodes. The electrical properties and film morphology of these chemically modified polymers were found to be strongly affected by the annealing temperature. For instance, heating glycerol doped poly(3-methoxy-5-(2′-ethylhexyloxy)thiophene)poly(pentylpyrrole) at 150°C resulted in a loss of conductivity, whereas the boiling point of glycerol was necessary to optimize its surface sheet resistance for use as polymer anodes in high performance MOLEDs.

2.7-carbazole-based polymers and oligomers are a new class of organic conjugated materials that give access to a wide range of molecular structures having optical and electrical properties. Depending on the targeted application, these materials may be easily tuned via chemical structure modifications to meet all requirements for the development of highly efficient devices, such as organic light-emitting diodes (OLEDs), organic field-effect transistors (OFETs) and organic photovoltaic cells (OPVCs). In OLEDs, poly(N-alkylcarbazole-2,7-carbazole) has demonstrated very good performances as a stable blue emitter. Electroluminescence as high as 60 cd/m² at 10 V has been obtained with device efficiency of 0.65 cd/A. The synthesis of other large band-gap 2,7-carbazole-based polymers helped us to improve the device performances. It has also been possible by using different co-monomers to get pure green and red light emission. Moreover, 2,7-carbazolevinylene-based materials have led to an easy access of very pure and well-defined oligomers, particularly promising for p-type OFET applications. Indeed, hole mobility as high as 1.7 x 10⁻³ cm²/V.s with an excellent m intrinsic ratio of 10⁶ have been obtained for many of these oligomers in optimized device configurations. On the basis of the hole mobility obtained in OFETs, it was then assumed that low-band-gap polymers derived from 2,7-carbazolevinylene unit should be excellent candidates in OPVCs. Preliminary results from such polymeric photovoltaic devices will also be reported.

11:45 AM 112.0
Hot Wire Chemical Vapor Deposition as a Novel Synthetic Method for Electroactive Organic Thin Films.
Cillian A. Zaharias, Helen H. Shi and Stacey F. Bent; Chemical Engineering, Stanford University, Stanford, California.

The synthesis and deposition of semiconducting organic thin films has been an active area of research since discoveries that such films can be used to make cheap, flexible electronic devices. A major obstacle in the production of large, high-quality, electroactive organic films is the instability of the necessary conjugated polymers, which makes spin-coating into thin films very difficult. In addition, synthesizing these materials in solution often produces environmentally hazardous byproducts. We are exploring the use of hot-wire chemical vapor deposition (HW-CVD) as an alternative, solvent-free technique to produce compact polyconjugated films from vaporized monomers such as pyrrole, acetonitrile and aniline. Our most promising results to date come from our attempts to deposit polyaniline, a polymer with a wide variety of optoelectronic applications, many of which have been limited by the complexity of processing the polymer. Infrared, UV-visible and X-ray photoelectron spectra have been obtained to characterize HW-CVD films produced using aniline as a precursor. The aromatic ring structure, essential for the polyconjugated network that leads to semiconducting properties, is largely preserved in our method. Careful tuning of CVD conditions is, however, required to minimize monomer fragmentation while still producing measurable film growth. These results suggest a growth mechanism involving competition between radical-initiated polymerization and destruction.

SESSION 113: Organic Electronics and Optoelectronics Chair: Bruce Friday Afternoon, April 16, 2004 Room 2018 (Moscone West)

1:30 PM 113.1

Active matrix organic light emitting diode (AM OLED) display fabricated on a flexible plastic substrate has potential for being lower cost, lighter weight, lower power and highly rugged with superior image quality, compared to the current glass substrate based AM LCDs. Amorphous silicon (a-Si) technology offers the potential for fabricating high mobility active matrix backplanes on low-temperature (<150°C) plastic substrates for producing AM OLED displays. We have developed the low-temperature a-Si TFT processes, and the backplane electronics designs to fabricate and successfully demonstrate a-Si-OLEDs using 4''-size flexible plastic substrates. In this paper we will first discuss the development of the low temperature a-Si TFT, and the backplane designs and processes used in this demonstration. We will then discuss the design and process technology challenges including management of thermal stresses due to CTE mismatch and lack of dimensional stability of the flexible plastic substrate, and the approaches for developing large area AM OLEDs on flexible plastic substrates.

2:00 PM 113.2
Development of high current efficiency and long life organic LEDs having charge generation layers. Janji Kid0 and Toshibo Matsumoto2; 1Polymer Science and Engineering, Yamaga University, 4-3-16 Jonan, Yamagata, Japan; 2IMES, Fujisawa, Kanagawa, Japan.

A new type of organic LEDs having charge generation layer (CGL) were developed. By applying voltage, holes and electrons are generated at CGL and adjacent organic layers to recombine with the carriers with opposite polarity. Thus, current efficiency can be greatly improved. An extremely high current efficiency of 65 cd/A, which is equivalent to 22 percent external quantum efficiency, was obtained from a device, using fluorescent emitter materials, having three CGLs. The lifetime of the device is over 6000 hours at the initial luminance of 11000 cd/m².

2:30 PM 113.3
Total Field Screening in Organic Light-Emitting Diodes. John C deMello1, Paul J Brewer1, Andrew J deMello1, Donal D C Bradley2 and Paul A Lane2; 1Chemistry, Imperial College London, London, United Kingdom; 2S. Draper Laboratory, Cambridge, Massachusetts.

We report electroabsorption (EA) measurements on operational organic light-emitting diodes (OLEDs). The measurements show complete elimination of the EA signal above device turn-on, indicating full screening of the internal field by the injected charges. The charge transport mechanism in these devices closely resembles that observed in light-emitting electrochemical cells (LECs), with charges moving primarily under the influence of diffusion. We discuss the origin of the screening phenomenon, and present drift-diffusion based modelling studies to rationalize the observed behaviour. The field-free bulk has far reaching implications for device operation, in particular when used as bulk transport and exciton dissociation and recombination processes are all field dependent.

3:15 PM 113.4
Improved light extraction from polymer LEDs with stipped Bragg gratings. Jonathan M Zieberth and Michael D McGhee; Geballe Laboratory for Advanced Materials, Stanford University, Stanford, California.

In normal polymer LEDs, light extraction is reduced by total internal reflection, which typically causes fifty to eighty percent of the emitted photons to be trapped in the polymer. By increasing the extraction of light from polymer LEDs, equivalent brightness levels can be achieved at reduced currents and drive voltages. This is extremely attractive for flexible polymer LED displays because reduces power consumption and operating temperatures while increasing the operating lifetimes. We have increased the external efficiency in the forward direction by more than 70 % by using a Bragg grating to scatter light out of the polymer film. The gratings are made by using holographic and soft lithography techniques. In order to optimize the outcoupling efficiency of the grating, we have empirically varied the thickness, grating depth, grating location, and optical properties of the microtextured layers and electrodes. We have also investigated geometrical structures to determine the waveguide mode and absorption loss. We find that it is important to use an LED structure that is slightly different from that of conventional polymer LEDs in order to minimize waveguide losses. One of the key issues is using a low loss metal (e.g. silver) over a very thin layer of calcium, which is needed because of its ability to efficiently inject electrons into the polymer. The angular distribution and polarization of the scattered light is in good agreement with the waveguide model.

3:30 PM 113.5
Polymer Based Photodetectors. K S Naraynan, Dinesh Kabra and Soumya Dutta; Jawaharlal Nehru Centre for Advanced Scientific Research, (JNCASR), Bangalore, India.

Recent developments in our laboratory related to polymer-based light sensors are reviewed. The inherent processability of the active polymer medium is utilized in the implementation of different designs for the opto-electronic applications. The utility of these devices as sensitive photodetectors, image sensors and position sensitive detectors is demonstrated. The schottky-type current generation properties of polymers such as polyalkylthiophenes and aluminum and the enhanced photo-induced charge separation due to high local electric field is tapped for these device applications. The sensitivity of polymer-based field effect transistors to light is due to the convenient lateral geometry where light can be coupled and controls the transistor state. The range of these polymer-detectors available in the sandwich and planar type configurations along with the option of operating in the diode and transistor mode should be an attractive feature for many potential applications.

4:00 PM 113.6
Organic switches for memory applications. Linn Domenica Boffano, Kenneth R. Carter, Vaughn R. Deline, Jane
Motivated by the need for low voltage solid state crosspoint memory elements, we have fabricated metal-organic layered structures and metal-polymer-blend devices designed to have bistable properties. Depending on the history of the device, the current-voltage characteristics of the devices exhibit multiple states at a fixed voltage in the low voltage regime (0-2.5 V). The current density changes by up to 5 orders of magnitude. The extreme values of the device current at 1V are associate to the ON and OFF states (or 1 and 0) used for memory and can be set by applying voltages corresponding to the maximum and minimum in the current voltage curve, respectively. The ON/OFF ratios, lifetime, switching time and retention time of the devices have been studied as a function of device structure, size and temperature. These properties are presented and discussed in term of charge storage.

4:15 PM 113.7
Light Sensitive Polymer Thin Film Transistors Based on BAS-PPE, Yifan Xu', Paul R. Berger', James N. Wilson' and Uwe H.F. Bunz'; 1Department of Electrical Engineering, The Ohio State University, Columbus, Ohio; 2Department of Physics, The Ohio State University, Columbus, Ohio; 3School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, Georgia.

The photoreponse of 2,5-bis(dimethylaminostyryl)-1,4-phenylene-b-alkyne-b-1,4-bis(2-ethylhexyl)benzene terpolymer (BAS-PPE) based polymer field effect transistors (PFET) is investigated. BAS-PPE is a photoluminescent conducting polymer with a bandgap of 2.25 eV. The BAS-PPE PFETs were fabricated using an open coplanar configuration and light is illuminated onto the top side of the PFETs. A sweep of V_{DS} demonstrates that I_{DS} saturation is suppressed during illumination, which suggests that pinch-off cannot be reached since the injected photo-generated carriers continues unabated. Also, with incident light, the channel can not be turned off, even at high positive gate biases, due to the accumulation of photo-generated carriers. A sweep of V_{DS} also shows that BAS-PPE is a p-type polymer and favors hole injection and transport. A sweep of I_{DS} versus V_{GS} demonstrates that under darkness I_{DS} is smallest at around 10 V gate bias, and then increases with more positive V_{GS}. It is surprising that I_{DS} under darkness at 40 V gate bias is even higher than at -40 V, even though there is carrier injection in addition to thermal generation at negative gate bias. Negative gate bias attracts holes to the polymer/insulator, and some holes may be trapped at this interface, while a positive gate bias expels holes from the polymer/insulator interface and far fewer holes are trapped there. Therefore, at positive gate biases, more holes are collected at the drain electrode resulting in a measured higher I_{DS}. A sweep of V_{GS} also shows an increase in I_{DS} with different light intensities. Comparing the data at V_{GS} at -40 V, 0 V and 40 V, we find that at zero gate bias the highest I_{light}/I_{dark} ratio is achieved. The I_{light}/I_{dark} ratio reaches as high as about 6000 at a light intensity of 71.5 mW.