SYMPOSIUM U
Printing of Materials in Photonics, Electronics, and Bioinformatics

April 13 - 15, 2004

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* Invited paper
Polymer field-effect transistors defined by self-aligned inkjet printing with submicrometer resolution, Christoph Schöpflin, Timothy von Werne, Wilhelm T.S. Hück, Sirringhaus, Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom; Plastic Logic Ltd, Cambridge, United Kingdom; Chemistry, University of Cambridge, Cambridge, United Kingdom.

The field of plastic electronics has experienced impressive growth in recent years and promises the realisation of flexible displays and smart labels. Inkjet printing is a promising patterning method for polymeric field-effect transistors, the basic building blocks of flexible circuits. It enables the fabrication of multilayer structures by additive deposition of solution-processable materials. For the fabrication of all-polymer electronic circuits it is desirable to minimize the channel length of the underlying transistors. This enables satisfactory switching speeds, despite the lower mobilities of many polymeric semiconductors compared to amorphous silicon. The achievable resolution using standard inkjet printing is limited to approximately 20 microns by droplet variations. Increased resolution has been demonstrated previously but requires pre-patternning of the substrate into hydrophobic and hydrophilic regions to confine the ink droplets. We present here a new self-aligned inkjet printing technique capable of submicrometer printing without the need for high-resolution lithography. The method is based on using the surface repulsion between a first inkjet deposited conducting pattern, for example a metal or a conducting polymer, such as poly(3,4-ethylenedioxythiophene)/poly(styrenesulfonate) (PEDOT/PSS), and subsequently deposit droplets of a second conductive pattern. The latter dewet from the surface of the first close proximity to form a pattern to produce sub-100 nm gap structures for FET devices without the need for any high resolution lithography. We use this powerful and simple printing-based nanostructuring method to reproducibly pattern sources and drains of devices with channel lengths of less than 100 nm, for all-polymer field-effect transistors.

Studying Charge Transport in Ink-Jet Printed All-Polymer Transistors, Yvonne Y Deng and Henning Sirringhaus, Optoelectronics Group, Department of Physics, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom.

Organic field-effect transistors (FETs) have been of increasing academic and commercial interest recently. In the quest for materials which combine high performance with the stability required for ink-jet printing in ambient conditions, poly(9,9-diocetylfluorene-co-bithiophene)(F8T2) has emerged as a promising semiconducting polymer. All-polymer FETs made entirely by ink-jet printing and spin-coating have been demonstrated, however, the charge transport physics at polymer-polymer interfaces is not well understood. Charge Modulation Spectroscopy (CMS) is a powerful tool to study the nature of charge carriers that give rise to the current flow in a polymer FET. The technique records changes of the optical absorptions on changing the gate-voltage-induced modulation of the charge-carrier concentration in the accumulation layer of the FET. Thus it allows direct observation of the polaronic relaxation of the charges in the FET channel. The technique is very sensitive to the properties of the semiconductor-dielectric interface and we present here, for the first time, the charge-induced absorptions of polaronic charge carriers in the accumulation layer of an inkjet printed all-polymer FET. Clear evidence for the formation of a clean accumulation layer is observed and it is clear that at hybrid interfaces with inorganic dielectrics, such as SiOx. We have performed CMS measurements on uniaxially aligned F8T2 films to investigate the polarisation of the observed charge-induced absorptions parallel and perpendicular to the alignment direction. Two different transitions are observed, one polarised, one unpolarised. Further, we have studied the dependence of the absorptions on the roughness of the active interface, using both, annealing treatments and variations of the dielectric solvent. We have also investigated the changes of the CMS spectrum upon bias stressing of the FETs, yielding valuable information about the mechanisms for threshold voltage shifts commonly observed in organic FETs.


Hewlett-Packard's successful thermal ink jet technology is sometimes perceived as limited to water based inks. In fact thermal ink jet can print a large variety of materials. Examples are organic solvent based systems, colloidal dispersions of nanoparticles, inorganic solutions, polymer light emitting materials, color filters, and adhesives. The presentation will address the fundamental materials landscape, show examples of printed devices, and outline the path to commercial print systems and applications.
been inadequate for RFID applications. The two most widely printed organic semiconductors are polythiophene and P3HT2; both have mobilities as high as 0.1 cm²/V.s at 10⁻⁶. However, the performance of these devices is crucial. Last year, we reported on the development of an ink-jettable pentacene precursor. Here, we report optimization schemes for the same via control of jetted film thickness and morphology, and demonstrate transistors with mobilities as high as 0.1 cm²/V.s at 10⁻⁶. Also we measure fmax to be as high as 1MHz in an unoptimized geometry. This ink-jetted transistor technology thus provides the highest performance reported for an ink-jetted transistor to date, with AC characteristics that are likely adequate for RFID applications.

11:30 AM U1.4
Printed Polymeric Transistor Arrays for Display Backplanes.
Byungkyun Kim, Ki Jun Kim and Dong Sik Zang; SAMSUNG SDI Co., LTD, Yongin-City, Gyeonggi-Do, South Korea.

In the manufacture of PDP panels, the phosphors are applied to an inner panel surface by screen-printing patterns of pastes containing red, green, and blue-emitting phosphors, respectively. But, paste should be formulated to minimize any negative effects on phosphor brightness during panel manufacturing. The organic components of the paste are burned out during panel manufacturing by heating the panels to about 500°C in an oxygen-containing atmosphere for about 1-2 hours. In this step, the pressure and the color coordinate of the PDP phosphors, particularly, those phosphors which contain activator ions sensitive to oxidation, e.g., BaMgAl11O17:Eu²⁺, BAm phosphor has a few problems to overcome for the application to PDP. For instance, a typical brightness loss for an organic paste composition, which maintained about 98% of the initial brightness (relative to the usage curve, and the brightness is too low for RFID applications. Furthermore, there have been no studies on the AC performance of these materials. Since RFID will likely require operating frequencies of either 135kHz or 13.56MHz, knowledge of the AC performance of these devices is crucial. Last year, we reported on the development of an ink-jettable pentacene precursor. Here, we report optimization schemes for the same via control of jetted film thickness and morphology, and demonstrate transistors with mobilities as high as 0.1 cm²/V.s at 10⁻⁶. Also we measure fmax to be as high as 1MHz in an unoptimized geometry. This ink-jetted transistor technology thus provides the highest performance reported for an ink-jetted transistor to date, with AC characteristics that are likely adequate for RFID applications.

11:45 AM U1.9
Polymer for phosphor in PDP Binding Application.
Byungkyun Kim, Ki Jun Kim and Dong Sik Zang; SAMSUNG SDI Co., LTD, Yongin-City, Gyeonggi-Do, South Korea.

In the manufacture of PDP panels, the phosphors are applied to an inner panel surface by screen-printing patterns of pastes containing red, green, and blue-emitting phosphors, respectively. But, paste should be formulated to minimize any negative effects on phosphor brightness during panel manufacturing. The organic components of the paste are burned out during panel manufacturing by heating the panels to about 500°C in an oxygen-containing atmosphere for about 1-2 hours. In this step, the pressure and the color coordinate of the PDP phosphors, particularly, those phosphors which contain activator ions sensitive to oxidation, e.g., BaMgAl11O17:Eu²⁺, BAm phosphor has a few problems to overcome for the application to PDP. For instance, a typical brightness loss for this blue-emitting PDP phosphor can be greater than 20% following burn out in air. Simultaneously, the chromaticity is changed from blue to green-like along with the degradation of its phosphor efficiency. Therefore, it is necessary of the present paper to minimize the decrease in the brightness and the change of color coordinate of PDP phosphor resulting from the burn out of the organic paste components. To overcome those problems, ethylcellulose, poly(butyl methacrylate), poly(butyl PEO) and poly(ethyl methacrylate), poly(vinyl butyral), polyethylene oxide, polypropylene carbonate, poly(methyl methacrylate), poly(ethyl vinyl acetate), poly(isobutyl methacrylate), and poly(o-styrene) etc. were investigated. However, since the polyethylene oxide (PEO) carries its own oxygen enough to burn itself, it is possible to burn out the phosphorous paste in N2 atmosphere. The paste for PDP comprising a phosphor dispersed in an organic solvent is well known that PEO retains at least about 95% of its initial brightness after binder has burned out and little change of color coordinate. Upon decomposition, it leaves very low ash residues with complete burnout of carbon. The TGA data showed that 35% binder content in the paste in a final part of the residual ash content of less than 2ppm. In addition, PEO is soluble in many common solvents, such as water, benzene, alcohols, chloroform, esters, etc. The preferred paste composition, which maintained about 98% of the initial brightness of the carbon residues, and the brightness is too low for RFID applications. Furthermore, there have been no studies on the AC performance of these materials. Since RFID will likely require operating frequencies of either 135kHz or 13.56MHz, knowledge of the AC performance of these devices is crucial. Last year, we reported on the development of an ink-jettable pentacene precursor. Here, we report optimization schemes for the same via control of jetted film thickness and morphology, and demonstrate transistors with mobilities as high as 0.1 cm²/V.s at 10⁻⁶. Also we measure fmax to be as high as 1MHz in an unoptimized geometry. This ink-jetted transistor technology thus provides the highest performance reported for an ink-jetted transistor to date, with AC characteristics that are likely adequate for RFID applications.

1:30 PM U2.1
Novel Materials for Dry Printing Electronic Devices.
Graciela Blanchet¹, John Rogers², Colin Nuckolls³, Greg Jaycox³, Michael Lefenfeld³ and Juelt-Lin Lo³; 1DuPont, Wilmington, Delaware; ²Columbia University, New York, New York; ³University of Illinois, Urbana-Champaign, Illinois; ⁴University of Texas, Austin, Texas.

Organic electronic systems offer the possibility of lightweight, flexibility and large area coverage, properties not easily achievable with standard silicon technology, and at potentially lower manufacturing costs. DuPonts approach to the fabrication of electronic devices is thermal transfer, a laser assisted imaging technique appropriate for their early commercialization. Since complex multi-layer circuits are fabricated by the sequential printing of films, the material options is considerably broadened and the stringent solvent compatibility issues facing wet techniques like micro-contact printing and ink jet are effectively circumvented. We continue to focus on the development of conducting and semiconducting organic composites that allow for the printing of active and passive electronic devices at good process speeds and high resolution. The feasibility of using laser ablation for large area printing of organic electronic devices was demonstrated by fabricating a 32 inch diagonal thin, flexible and ultra-light weight organic transistor array backplane.

2:00 PM U2.2
Printing of Polydiacetylene Vesicle Patterns on Glass.
Dong June Ahn¹, Sang Hoon Lee¹, Hee-Yong Shim¹, Sung Min Woo¹, Eun-Kyung Kim² and Jong-Man Kim²; ¹Department of Chemical & Biological Engineering, Korea University, Seoul, South Korea; ²Department of Chemical Engineering, Hanyang University, Seoul, South Korea.

Polydiacetylene-based vesicles are interesting materials in view of application to chemical and biological sensors. These vesicles are unique in changing color from initial blue to red upon specific binding events, caused by shortening of delocalization length of π-electrons along diacetylenic backbones. Various binding events including viruses, toxins, glucose, and ionic interactions have been reported. However, simultaneous screening of various binding events has not been possible with solution-phase vesicles. Recently, we were successful in immobilization of the polydiacetylene vesicles on glass substrates without losing their unique color changing property (Adv. Mater. 2003, 15, 1118). In this presentation, we report on printing of polydiacetylene vesicles on glass substrates by using laser ablation technique to make microscale dot patterns. Each dot is found to possess the color-changing property as well as the fluorescence emission. This technique allows us, for the first time, to fabricate biosensors along polydiacetylene vesicles and to screen binding events simultaneously.

2:15 PM U2.3
Soft Lithography for Ultraminiaturized Biological Assays.
Eugene Delamarche, Sandro Groenendijk, Heinz Schmid, Marc Wolf, Helko Wolf, Bruno Michel and Walter Riess; Science & Technology, IBM Zurich Research Laboratory, Ruschlikon, Switzerland.

Depositing proteins as small spots on surfaces opens the way to miniaturizing biossays with the attendant benefits of economizing reagents, detecting analytes in parallel with high-quality signals and in minimal time. We have developed methods based on soft lithography to pattern proteins down to the level of a single protein molecule. The proteins are patterned on surfaces for biochemical applications. Soft lithography refers to a set of techniques that utilize a soft element to pattern a substrate with small molecules, polymers or biomolecules. This element is typically a micropatterned elastomer, and it can be placed reversibly onto a surface without damage. In so-called microcontact printing, the element is a stamp, and it is simple to adsorb proteins from solution onto the stamp for printing on a variety of substrates with submicrometer accuracy. For example, micrometer-wide areas of a silicon surface can be printed with a thousand antibody molecules and used for surface immunosassay.
We have fabricated patterned polyp(N-isopropylacrylamide) brushes on oxidized silicon wafers by the micro-contact printing of a self-assembled surface initiator followed by the surface-initiated atom transfer radical polymerization (ATRP) of N-isopropylacrylamide (NIPAAm). The patterning of the surface initiator was achieved by micro-contact printing of octadecyltrichlorosilane (OTS) followed by backfilling with poly(ethylene glycol) monomethyl ether dilithium salt and aminated amino group was reacted with bromoisobutyric acid. The surface-initiated ATRP of NIPAAm was carried out in methanol/water mixture using CuBr/pentamethyldiethylenetriamine (PMDETA) as the catalyst system. The thickness of the PNIPAam brush thickness can be varied from a few nanometers up to about 50 nm. The chemical structure of the PNIPAam brushes was confirmed with X-ray Photoelectron Spectroscopy and Fourier Transform Infrared Spectroscopy, and the physical properties have been characterized with ellipsometry, contact angle measurements, and X-Ray Reflectometry. Atomic Force Microscopy and Fluorescence Microscopy have confirmed the success in the micro-patterning of the PNIPAam brushes. The fluorescence emission spectra of Prodan in the PNIPAam brushes have indicated that the local chemical environment of PNIPAam is very similar to that of DMF. In the fluorescence microscopy image of Prodan in patterned PNIPAam brushes grafted on silica cover slip, the intensity of Prodan emission is stronger than that on OTS because the Prodan molecules can be strongly attracted to the brush layer. The patterned PNIPAam brushes on oxidized silicon wafers or silica substrates may be useful for many applications including surface-confined molecular delivery, biomolecular sensing, and molecular separation.

3:30 PM *U2.5
Directed self-assembly of nanoparticle building blocks onto charged based receptors. Hoko Otto Jacobs, Chad R. Barry and Anam. M. Smith; Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, Minnesota.

Nanoparticles are considered potential building blocks for the fabrication of future devices. This article reports on a new tool to direct the assembly of nanoparticles onto surfaces using electrostatic forces. We demonstrated directed self-assembly of nanoparticles onto charged surface areas (receptors) with a resolution of 100 nm. The charged based receptors required for this type of directed self-assembly were fabricated using a parallel method that employs a transparent particle assembly module to direct and monitor the self-assembly of nanoparticles. The charged based receptors were designed to enable the patterning of and electrostatic forces onto the surface of the substrate. The receptors were then bound to the substrate through a layer of charged surfactant. The patterned receptor was then exposed to a suspension of nanoparticles and microfluidic networks were formed. The nanoparticles were then selectively captured onto the receptor and the assembly of the material was confirmed by measuring the change in capacitance. The use of such a method enabled the fabrication of complex structures and devices with high resolution and contrast using submicrometer quantities of samples and reagents, and on a time scale of a few minutes. These biopatterning methods were demonstrated as proof-of-concepts and as very exciting to try them for advanced bioassays.

4:00 PM *U2.6
Additive Contact Printing of Conductors for Thin Film Electronics. Yu-Shi Lin Lin, Kwang Seok Lee and Kimberly C. Furst; Dept. of Chemical Engineering, The University of Texas - Austin, Texas.

Recent advances in printing technologies have been fueled by the high costs associated with lithography tools and techniques. More importantly, contact printing, unlike conventional lithography, promises to be compatible with a wide range of materials and substrates. Recently, we have developed two contact printing schemes for i) direct patterning of conductive polymers from an aqueous dispersions and ii) additive printing of copper. These methods are straightforward and versatile, and we have fabricated electrical components for both sub-micrometer thin film electronics with these. Furthermore, these methods are additive in operation so sacrificial resists, developers, and etchants are no longer required. Conductive polyaniline (PANI) is an attractive candidate for all-polymer electronics because of its chemical and environmental stability. Yet, due to its intractability, fabricating functional PANI electrical components remains challenging. Our patterning scheme involves a water-soluble PANI formulation and begins with patterned deposition of octadecyltrichlorosilane (OTS) on a hydrophobic substrate. The treated substrate is then dip-coated with the PANI formulation. Due to specific interactions between the polymer and the substrate, PANI only adheres to the untreated, hydrophilic regions. Conductive PANI patterns, with feature sizes as small as 20 microns, can be transferred on to the substrate by a simple physical means, and the ability to additively pattern Cu is highly sought after because of the ability to selectively deposit Cu at desired locations. This technique is applied to print Cu. Specifically, thiol-terminated molecular layers are incorporated as transfer layers to pattern Cu patterns on the substrate. In doing so, the conductivity of the Cu patterns is highly dependent on the chemical nature of the substrate and the pattern etching process. We have achieved a conductivity comparable to evaporated Cu films of similar thicknesses.

4:30 PM *U2.7
Programmable Ferrofluid Masks for Lithographic Applications. Benjamin Biron Yellen and Gary Friedman; Electrical and Computer Engineering, Drexel University, Philadelphia, Pennsylvania.

Fabrication of heterogeneous substrates, like the kind used for combinatorial chemistry, genomic microarrays, and drug discovery, requires multiple lithographic patterning steps with appropriate alignment between the patterns in each step. Such heterogeneous substrates have been successfully fabricated by photolithography in the past, however traditional photolithographic techniques are expensive, chemically intensive, and laborious, requiring multiple steps to produce even a single pattern. Furthermore, manual alignment of many different masks to the substrate becomes increasingly difficult to control when the critical feature size is nanoscale or even sub-micron in resolution. A novel soft masking method is presented here that employs programmable alignment marks built into the substrate to define and automatically align sequences of masking patterns. This method uses ultra-fine iron oxide grains suspended in fluid (ferrofluid) to protect or de-protect selected areas of a magnetically patterned substrate according to a programmable sequence. Ferrofluid can act as both an optical mask and a diffusion mask. Its ability to act as an optical mask is first demonstrated with commercially available positive and negative photoresists. Ferrofluid is allowed to assemble into a thin film on top of the photoresist. The competition between external bias fields and the fields produced by the alignment marks causes ferrofluid masks to assemble only over designated areas. After exposure to 354 nm radiation, the ferrofluid mask is rinsed away and the photoresist patterns is developed. The resulting photoresist patterns are used by the lift-off process to produce an array of evaporated metallic islands with typical spot size of 8 nm. Because of the self-alignment of the spots, the mask is then used to position the alignment marks with sub-micron resolution. However, the lithographic applications of ferrofluid masks are not limited to just optical masking. Ferrofluid can also be used as a diffusion mask directly to the surface during solution-based synthesis, thereby combining mask formation and material deposition into a single step. Moreover, ferrofluid masks are easily dissolved without intensive chemical strippers. This gentle synthesis approach can potentially be applied to multiple layers of delicate biological materials like proteins and cells.

4:45 PM *U2.8
Charge Patterning and Decay on Polymethylmethacrylate (PMMA) Films on Different Substrates - a Template for
Guided Assembly. Fengting Xu and John A Barnard; Department of Materials Science & Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania.

Unique opportunities exist for utilizing nanoscale charge patterning for directed electrostatic assembly of complex functional nanostructures from discrete charged/polarized nanoparticles (e.g., colloidal spheres) or macromolecules. In this work, anime-terminated poly(amideamine) (PAMAM) dendrimers with positively charged end groups were used as the assembled species. First, conductive atomic force microscopy (AFM) tips were used to charge writing/reading poly(methylmethacrylate) (PMMA) films spin-coated onto n-type doped Si (111) and mica substrates. The substrate effects on the charging process and its decay over time were studied. Both the positive and negative charged dots on both substrates exhibited significant charge dissipation over a period of hours although the positive storage on PMMA/Si was still evident for a few days. The measured time scales are appropriate for guided assembly processes. Second, the charged patterns of PMMA films were submersed into a dendrimer containing solution and the pattern formation due to the electrostatic force between the negative charged regions on the PMMA films and positive charged dendrimer end groups were investigated.

SESSION U3: Poster Session
Tuesday Evening, April 13, 2004
8:00 PM
Salons 8-9 (Marriott)

U3.1
Microcontact printing and selective atomic layer deposition. Mi H. Park, Ki Y. Ko and Myung Mo Sung, Chemistry, Koinkum University, Seoul, South Korea.

We demonstrate a selective atomic layer deposition (ALD) of TiO2 thin films on patterned self-assembled monolayers formed by microcontact printing. This technique has been used successfully to deposit TiO2 features with sizes ranging from 5 to 0.15 um on technologically important substrates including silicon and glass. The patterned monolayers on these surfaces define and direct the selective deposition of the TiO2 thin film using atomic layer deposition (ALD) technique involving the reaction of titanium isopropoxide and water as the precursor. The patterned ALD TiO2 thin films have been investigated by atomic force microscopy (AFM), x-ray photoelectron spectroscopy (XPS), contact angle analysis, x-ray diffraction (XRD), transmission electron microscopy (TEM), and UV spectrometer.

U3.2
A new soft lithographic method by using cohesive mechanical failure patterning of PDMS decal stamp. Eun K. Seo, Kyung S. Park and Myung Mo Sung; Chemistry, Koinkum University, Seoul, South Korea.

Decal transfer micro lithography (DTM) is a new soft lithographic method for micro/nano patterning. We have demonstrated micro/nano scale patterning via cohesive mechanical failure (CMF) version of DTM. In this decal pattern transfer process, the features of a patterned PDMS decal stamp are physically torn from it via a cohesive mechanical failure, CMF is a convenient technique for fabricating patterned micro/nanostructures of PDMS on a variety of solid substrates. High-resolution patterns can be formed by CMF. We demonstrate a selective atomic layer deposition of TiO2 thin films on patterned polymeric micro/nanostructures formed by CMF. The patterned polymeric structures can be also used as resists in the wet etching of underlying films.

U3.3
An Affordable and Flexible Hot Embosser Design. Robyn R. Reed, Joanna L. Payne, Nisha D. Patel, Karen E. Legal and Diana D. Glawe; Engineering Science Department, Trinity University, San Antonio, Texas.

Hot embossers can be used to imprint patterns into polymers for microfluidic and optical applications, among others. As part of a senior design project, a group of four students has designed a relatively inexpensive automated hot embossing machine based on a commercial hydraulic press platform coupled with custom designed platens, hydraulic control, and sensor configuration. The hot embosser is controlled using a desktop computer and LabVIEW software, both of which are commonly available at research institutions. Using LabVIEW to control the system permits the integration of additional sensors, thus adding flexibility to the system. The total cost of the equipment, excluding the desktop computer and LabVIEW software, is less than $1,000, making this an affordable design compared to similar devices.

U3.4
Photo-patterning of poly(3-dodecylthiophene) by means of photoinduced surface relief formation as a molecular conveyer. Nobuyuki Zettu1,2, Takashi Ubukata2, Masahiko Hara2 and Takahiro Seki2; 1 Chemical Resources Laboratory, Tokyo Institute of Technology, Yokohama, Japan; 2 Frontier Research System, RIKEN, Wako, Japan; 3 Nagoya University, Nagoya, Japan.

π-Conjugated polymers are promising as active materials in many application areas such as microelectronics and photonics. Their imaging is a key technology in device fabrication processes. Patterning of π-conjugated polymers has been achieved through some advanced techniques such as micro-molding in capillaries (MIMIC), microcontact printing (μCP), inkjet printing and so on. Most of such techniques required, however, complicated processes. We have previously shown that highly photo-sensitive surface relief formation (instant mass migration) in liquid crystalline azobenzene polymer films can be accomplished only with short exposure time (in the order of minutes). Sinusoidal trilayers originate from photoinduced polymer chain migration at micrometer levels. Construction of micro relief structures in this instant mass migration system is advantageous for facile and all optical step fabrication. Here we focus on the possibility for patterning of π-conjugated polymers using this light-driven instant mass migration system as a molecular conveyer.

The micro relief structures were made directly on the polymer blend films which consist of a liquid crystalline azobenzene polymer and poly(3-dodecylthiophene). The surface relief gratings were inscribed by two ways: 1) exposing the blend films to an interference pattern of s-polarized argon ion (Ar+) laser beams at 488 nm with 5mW cm-2, and exposure to an incoherent non-polarized blue light at 436 nm (g-line of mercury lamp) through a photomask attached to the film. The inscriptions were characterized by atomic force microscopy, fluorescence microscopy and microscopic fluorescence spectroscopy. The clear fluorescence patterns corresponding to the higher part of the relief structures were observed. This result led to the conclusion that poly(3-dodecylthiophene) was transferred together with liquid crystalline azobenzene polymer with short exposure period. We could obtain various patterns of poly(3-dodecylthiophene) with all optical processes resulting from the use of this instant mass migration system, in which the photo active host materials conveys other functional guest materials.

U3.5
Solventless Polymerization to Form Conducting Polymers in Nanochannels. Hongwei Gu and Bing Xu, Dept. of Chem., Hong Kong University of Science & Technology, Hong Kong, NA, Hong Kong.

Here we report a simple solventless polymerization procedure to form linear conducting polymers in nanochannels. When the surfaces of nanochannels of a template are covered with a Grubbs's catalyst vapor of cyclooctatetraene polymerizes inside the channels as highly oriented conducting polymers, whose electrical properties will also be described.

U3.6

Creating ordered arrays of single-walled carbon nanotubes (SWNTs) is critical for the realization of integrated carbon nanotube-based electronics. Utilizing a novel dry deposition technique, aligned SWNTs have been observed on the Si(100) surface by atomic-force microscopy (AFM) in ambient conditions. The dry transfer process is first performed under ultrahigh-vacuum (UHV), where solid phase HiPer SWNTs are deposited onto pristine UHV-prepared Si(100)-2×1:H surfaces [1]. A fiberglass applicator uniformly coated with SWNTs is brought into gentle mechanical contact with the Si sample, delivering predominantly individual SWNTs to the surface with minimal contaminants (catalysts and carbon residue). After removal from UHV, large area AFM scans show that the SWNTs exist almost entirely in the form of aligned arrays. The mechanisms underlying these observations will be discussed. An important aspect of the dry deposition process is that it can be generalized to the deposition of almost any species to surfaces that are not compatible with ambient exposure. One example of this that we will show is the ability to deposit SWNTs onto UHV-cleaved GaAs(110) surfaces and then achieve atomic resolution UHV STM images of both the SWNTs and the substrate [2]. Current experiments include using AFM and STM to characterize SWNTs on different surfaces, as well as to studying the effects of changing different variables in the dry transfer deposition process.

Although synthetic polymers have shown promise as viable alternatives for tissue repair and replacement, a shortage of suitable polymers remains due to the slow process of material development. As a first attempt to expedite polymer development, we propose and develop a polymer array system for the rapid screening of polymers for potential biomedical applications. Silanated tetraethylene glycol (TEG) was prepared for the modification of glass surface. It was synthesized by adding undecenyl moiety to TEG monomers together, followed by addition of dichloromethylsilane to the double bond. Then, cleaned glass surfaces were modified with TEG. The silane layer serves a dual role for providing protein resistance on the background (TEG society) and a hydrophobic domain for polymer attachment (undecenyl moiety). Eight tyrosine-derived polymers with a systematic variation in the chemical composition and physical properties were used. They were synthesized according to published procedures and dissolved in dimethylsulfoxide (DMSO) (1 wt percentage). Polymers were printed onto TEG-modified glass surfaces by a microarray printer. During the process, the first polymer was transferred from the bulk reservoir to the silanated surface by microarray pins, which were then washed by DMSO and water before printing a second polymer. The cycle was repeated for all test polymers. The polymer spots were then dried at room temperature and found to be stable under aqueous conditions. An immunofluorescence assay was used to obtain the adsorption profile of fibrinogen and fibronectin on individual polymers. During the assay, polymer arrays were incubated in a single protein solution (150 microgram/ml) for two hours, washed with phosphate-buffered saline and blocked with a mixture of bovine serum albumin (1 wt percentage). The surface-bound proteins are then recognized by fluorescence-tagged antibodies. Results from an immunofluorescence assay show that the adsorption profile of fibronogen on fibrinectin is different on individual polymers. A similar trend is also observed for fibronectin. Moreover, adsorption profile of fibrinogen is different from that of fibrinectin.

We describe the direct writing of copper lines with a digitally programmable technique. The copper lines are produced by the laser annealing of a metal-organic precursor, copper hexanate. Films of this metal-organic precursor with thicknesses of 1.6 and 3.2 micrometers are spun onto a glass substrate. The films are then scanned with a Nd:YAG laser beam (1064 nanometer wavelength), which thermally oxidizes the films to a copper-copper oxide mixture. For full conversion to metallic copper the films are annealed at 200 degrees C in hydrogen. We obtained various stages of film morphologies between the two phases. One is a fine crystalline and powdery film, with an appearance under the scanning electron microscope that suggests nucleation and growth of copper or copper oxide from a solid phase. The second phase is a frozen melt, indicating liquefaction as part of the conversion of the precursor. Both phases are electrically conducting. Our results demonstrate the feasibility of direct digital writing of copper conductors. This work is supported by ONR.

We report on a programmable, reconfigurable, printing approach for parallel nanofabrication of two different types of structures: patterns of charge for nanoelectrographic printing, and patterns of e-beam resist for nanofabrication. The developed tool is based on previous knowledge in the field of conductive scanning probe lithography, which uses a conducting probe to electrically expose and modify a surface. Our tool makes use of the same physical principles, however, instead of using a single electrical point contact, a conductive flexible electrode is used. This electrode is based on a flexible membrane that forms multiple electric contacts of different size and shape to the surface, exposing the entire surface to electrons and electric fields in a single step. The electrodes are used to expose e-beam sensitive resists to generate patterns of charge and topography with 100 nm resolution. Compared to the commonly used e-beam lithography, the electric nanocontact lithography provides a route to enable programmable, reconfigurable nanofabrication.

Silver nanoparticles have been synthesised from the silver salts of fatty acids, followed by addition of dichloromethylsilane to the double bond of the fatty acid. During the process, the first polymer was transferred from the bulk reservoir to the silanated surface by microarray pins, which were then washed by DMSO and water before printing a second polymer. The cycle was repeated for all test polymers. The polymer spots were then dried at room temperature and found to be stable under aqueous conditions. An immunofluorescence assay was used to obtain the adsorption profile of fibrinogen and fibronectin on individual polymers. During the assay, polymer arrays were incubated in a single protein solution (150 microgram/ml) for two hours, washed with phosphate-buffered saline and blocked with a mixture of bovine serum albumin (1 wt percentage). The surface-bound proteins are then recognized by fluorescence-tagged antibodies. Results from an immunofluorescence assay show that the adsorption profile of fibrinogen on fibrinectin is different on individual polymers. A similar trend is also observed for fibronectin. Moreover, adsorption profile of fibrinogen is different from that of fibrinectin.

Selective, Controllable, and Reversible Aggregation of Polylysine Latex Microspheres via DNA Hybridization. Antoine Calvès1, Phillip R. Martukanitz2, Sigurd Wagner1, James K. O. Lau2, Bradley Roberts3, Eric Michel3, David J. Pine3, and Peter V. Schwartz2; 1Physics, Cal Poly, San Luis Obispo, California; 2Materials Engineering, Cal Poly, San Luis Obispo, California; 3Chemical Engineering, UCSB, Santa Barbara, California.

Single stranded DNA is covalently attached to polylysine latex microspheres and the resulting surface coverage is measured for different attachment protocols. Increased DNA surface coverage improves charge stabilization (reduction in non-specific aggregation of microspheres) resulting from increased electrostatic repulsion. DNA derivatized microspheres aggregate in the presence of a DNA strand, the opposite ends of which are complementary to strands bound to the microspheres. In a mixture of microspheres derivatized with different sequences of DNA, microspheres with complementary DNA form aggregates, while microspheres with noncomplementary sequences remain suspended. The process is reversible by heating, absence of salt, and ultrasonic agitation.

8:30 AM U4.1 Materials Requirements for Successful Drop-On-Demand Ink Jet Deposition. Michael Grove, David Wallace and Donald Hayes; MicroFab Technologies, Inc., Plano, Texas, Texas.

The increasing use of instruments utilizing drop-on-demand, or demand mode, ink jet technology for the fabrication of micro-scale electronic, photonic, optical, biomedical, and pharmaceutical devices or products is leading to a greater interest among experimenters in these fields in this materials deposition process. This paper intends to discuss the materials requirements for the process that lead to successful ink jet printing experiments. While ink jet technology became a success in the 1980s and 1990s in the color printing of PC generated documents in the office and home environments after having gone through decades of research and development, it had a parallel development, if on a much modest scale, as a technology for the precise printing of pico-liter drops of fluids that were not aqueous solutions of acid dyes, cosolvents, glycols, stabilizers, and biocides. Non image producing ink jet printing developments include the fabrication of micro-templates, the printing of DNA and polypeptide diagnostic arrays on chips, the printing of molten solder on microprocessor bonding pads for flip chip assembly, printing of interior thick film resistors for PWB assemblies, conductive strips, organic field-effect transistors, conductive polymer structures, light
emitting polymers for OLEDs, and drug containing injectable microspheres for trans-dermal controlled release drug delivery among others. For finer structures, photo-lithography is used. In parallel one can fabricate electronic devices by printing techniques. In this paper we will discuss the fluids covered include both aqueous and non-aqueous solutions of low molecular weight and polymeric solutes, hot-melt printing of organic and metal melts, printing of nano materials, and printing of dispersions and suspensions. Acceptable and unacceptable substrate: the substrate will be examined. Successful ink jet deposition processes depend on achieving the desired materials interactions between the fluid and the substrate as well as between the fluid and the jetting device. Substrates used in the above described examples will be mentioned.

8:45 AM *U4.4 Inkjet Printing of Embedded Passive Components. Erik Moderegger1, Gewinner Leising1, Harald Plank2, Stefan Ganner2, Gennaro Maurice Picelli3, Christoph Gadermaier1, Oliver Werzer1 and Emil J W List2

The Effect of Environmental Conditions on Dip-Pen Nanolithography of Mercaptophecanecofonic acid. Erik Peterson2, Ivan Hromadch3, Matt Leyden3, Cheuk Tang3, Brandon Wecks3, James De Yoreo3 and Peter V. Schwart4

The direct patterning of mercaptophecanecofonic acid (MHA) from an aqueous solution by Dip-Pen Nanolithography (DPN) is investigated as a function of humidity, temperature, total elapsed time, and protocol for coating the AFM tip. The patterning process is directly observed by means of scanning electron microscopy (SEM). Like the DPN patterning of Octadecanethiol (ODT), MHA can be patterned under a dry atmosphere in apparent absence of any water meniscus. Unlike ODT, the molecular transport rate of MHA decreases in a near exponential fashion with an approximately 1-hour decay time, and substantially increases at very high relative humidity as a water meniscus is formed.


Fundamental understanding of structure-function relationship is of paramount to development of engineered biological tissue substitutes. This initiative has led to development of several suitable biomedical alternatives to native tissue transplantation. Microfabrication methods used for assisting this effort are being expanded to improve current capabilities. These include various printing technologies utilized in the assembly and patterning of biological material building blocks. One such method has been recently been demonstrated to be direct-writing of biological materials, previously termed DWB [1]. This method is an extension of the Maskless Mososcale Material Deposition or M3DTM technology. It features deposition of biological materials in computer-defined patterns on a variety of biocompatible substrates. Like the M3DTM process, an aerosol is first generated. Materials are then delivered to the desired target surface using a deposition head that generates a co-axial flow between the aerosolized material and a sheath of inert gas used for directing and shaping. Stock solutions containing biological molecules such as functional...
catalytic peptides and enzymes, somatic extracellular matrix, immunoreactive and fluorescing proteins, or oligonucleotides have demonstrated biofunctionalities for a wide range of biological molecules compatible to this direct-write deposition method. Hence, aerosols containing biologically active materials can be deposited into micro-patterned features and structures without loss of functionality due to denaturing. In addition, development of this process for whole cell encapsulation aims to provide additive value to computer-aided engineering of embedded architecture tissue constructs. The intention of this work is to elucidate the progress made in these areas.

11:45 AM U4.9
New Materials for 3D Printing of Bone Graft Substitutes with Controlled Internal Structures. Stephan H. Irsen, Hermann Seitz and Barbara Leukers; rapid prototyping, research center caesar, Bonn, Germany.

Bone grafts have been used for a long time to repair osseous defects from trauma or disease. While autografts are limited and difficult to shape, allo- or xenografts require extensive processing to minimize disease transmission. Thus, the development of a safe synthetic bone replacement is a worthy objective. Today, different synthetic bone replacement materials are available. Normally these materials are produced in simple geometries like blocks, pins or sponges. Rapid Prototyping and especially 3D Printing is well suited to generate custom ceramic bone replacement implants from patients' X-ray data in a short time. Here we filled a cavity with a ceramic powder is printed with a special binder solution layer by layer. The powder is bonded in the wetted regions. After, all, unfilled regions is removed and a ceramic green body is obtained. This green body obtains its desired mechanical properties by sintering. Different Apatites have been used as bone replacement materials. We use synthetic Hydroxyapatite (HA) powders for the fabrication of the 3D printed scaffolds. For bone replacement, HA is a promising ceramic material because of the similar chemical and morphological structure in comparison to the mineral portion of human hard tissue. From the process point of view 3D printing requires a powder with good flowability, a controlled particle size distribution and a suitable and strong binder interaction. Commercial HA powders do not fulfill these demands in general. We use various coating and agglomeration techniques e. g. spray drying and fluidized-bed technologies to produce granules suitable for the mentioned printing process. With those techniques we fabricate HA powders with a high flowability and bulk density and a mean particle size between 60 and 100 μm. Those powders are processed in combination with different water based binder solution which are optimized in means of surface properties and viscosity. For a good osteointegration and resorbability of the fabricated implants the internal structure of the macroscopic bodies and the used materials is very important. For a good osteointegration a mean pore diameter of 500 μm is discussed.

We produce 3D printed samples with a controlled internal pore network and a channel diameter between 600 and 800 μm. In addition to this printed pore network the ceramic parts posses a microporosity in the range between 10 and 100 μm. This microporosity is realized by multidirectional injection of the powder materials. The mechanical strength of the sintered parts I was tested and is comparable to commercial available xenografts. To ensure the safety of the ceramics, biological tests of the sintered parts and the base materials are pending.

SESSION U5: Nanoimprint Lithography and Direct Printing
Chair: Ghassan E. Jabbour
Wednesday Afternoon, April 14, 2004
Room 3022 (Moscone West)

1:45 PM *U5.1
Photonic and Biological Applications of the Nanoimprinting Technique. L. Jay Gao; University of Michigan, Ann Arbor, Michigan.

Nanoimprint Lithography (NIL) has emerged as a promising nanofabrication technology in recent years. NIL uses a hard mold to mechanically deform the polymer resist material to create nanoscale patterns, which completely free itself from the resolution-limiting factors such as light diffraction or beam scattering that are often inherent with other more traditional approaches. The nanoimprinting technique not only has the ability to pattern precise nanoscale features, it is also compatible with thermoplastic and other material processes. Based on these characteristics, we have applied nanoimprint to several polymer based photonic devices, including nanostructures in nonlinear optical polymers, high-resolution OLED pixels, and polymer waveguide devices. For the latter devices, we will discuss a specific type, namely polymer micro-ring resonators, fabricated by a direct imprinting technique, and its new application for biochemical sensing. Based on the principle of NIL, we have also developed a new approach to fabricate nanofluidic channels with well controlled dimensions, and we have studied the behavior of DNA molecules in such confinement channels. The nanochannel dimensions are fabricated by bonding a channel template into a thin polymer film cast on a glass cover slip in a simple step, offering a much higher throughput than previous methods. It is easy to control the nanochannel dimensions by a simple relationship involving the initial polymer layer thickness and the mold pattern configuration. We demonstrated effective DNA stretching in these nanochannels, which could lead to applications of quick mapping of genomic DNA segments in short time using very small amount of DNA samples. This method provides a simple and practical method for low-cost fabrication of nanofluidic channels, which may serve as a useful tool for chemical analysis system in the nanoscale.

2:15 PM U5.2
Barium-doped and Aluminum-doped Silica Gradient-Index (GRIN) Lenses by Slurry-based Three Dimensional Printing (S-3DP[TM]). Hong-Rei Wang1, Michael J. Cima1, Brian D. Kernan2 and Emanuel M. Sachs3, *1Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts; 2Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.

The traditional slurry-based three-dimensional printing (S-3DP[TM]) process has been used to fabricate complex structure materials by printing organic binders in selective positions of each printing layer. This process has been modified to fabricate the functional graded materials, such as gradient index (GRIN) lenses, by depositing different concentrations of dopant solution into selective positions. Two material systems, Al2O3-SiO2 and BaO-SiO2, have been chosen to demonstrate the fabrication of GRIN lenses. Aluminum nitrate and barium chloride, which decompose into alumina and barium oxide during heat treatment, are dissolved in deionized water and printed into the silica powder bed as the source of dopant. Continuous dopant jets and Drop-on-Demand (DoD) printing heads are used to control the dopant concentration profile in one dimension and two dimension, respectively. GRIN lenses with different concentration profiles are fabricated. The aluminia-doped silica powder beds are dehydrated at 1000 °C for 24 hours and sintered to optical transparency at 1650 °C for 30 minutes. The barium-doped silica powder beds are treated at 985 °C for 48 hours and sintered to optical transparency at 1700 °C for 30 minutes. Both sintering are done in a vacuum furnace (5x10^-6 torr). The dopant distribution after sintering are measured using electron probe microanalysis (EPMA) and compared with the design profiles. The resulting optical effects are examined by measuring the effective focal lengths of the GRIN lenses. The effects of alumina and barium oxide on the refractive index change are also compared.

2:30 PM U5.3
Direct Patterning of Functional Ceramics Films In/From Solution Without Post Firing. Masahiro Yoshimura, Tomoaki Ruwan Gallage and Ryo Teranishi; Tokyo Institute of technology, Yokohama, Japan.

Patterning of ceramic films has been established generally by [1]classical lithography after fabrication of continuous films by dry or wet methods, [2] direct printing of source materials in powder or their precursors, and then laser firing, [3] direct drawing of patterns with an ink or slurry, and then firing, mostly by firing, etc. Those processing consists of sophisticated multi-steps, which consume large amount of energies and resources and then leave most of those energies and materials as exhausts and/or wastes. We are proposing an innovative concept and technology, Soft Solution Processing (SSP) for Ceramics(1), which aims “direct fabrication of shaped, sized, located, oriented ceramic materials from solution(s) without firing and/or post-firing.” We have succeeded to fabricate thin film patterned of BaTiO3, SrTiO3, BaWO4, SmCo4, LiCoO2, LiNiO2, etc. by SSP in aqueous solution of RT-200°C(2). In those fabrications, interfacing reactions between a solid reactant (substrate) and component (s) in a solution have been designed and realized. When we fabricated the patterns, locally and moved the reaction point dynamically in those reactions, we can get patterned ceramics directly in solutions without post-heating, pattern forming, firing nor sintering. Recently we have succeeded to fabricate several patterned ceramics films i.e. BaTiO3,
Phase separation micro and nano molding, Laura Vogelsak\textsuperscript{1}, Jonathan Barrena\textsuperscript{1}, Lydia Bolhuis-Versteeg\textsuperscript{1}, Wietze Nijdam\textsuperscript{2}, Cees van Bijnen\textsuperscript{2}, and Matthias Weseling\textsuperscript{1}, \textsuperscript{1}MRS Symposium Group, department of science and technology, University of Twente, Enschede, Netherlands; \textsuperscript{2}Aquamirijn Micro Filtration, Zutphen, Netherlands.

Phase separation micro and nano molding (PS\textsubscript{m}/nM) is a generic replication method, which covers an unprecedented range of materials. Virtually any soluble polymer can be applied in phase separation, including e.g., biodegradable polymers and high Tg polymers. Furthermore, by optimizing the thermal processing PS\textsubscript{m}/nM can also be utilized for the fabrication of ceramic and carbon microstructures. During the phase separation, the replication process benefits from intrinsic shrinkage, which facilitates the fabrication of for instance open microstructures. Moreover, a small gap between the mold and the structure evolves due to shrinkage. Therefore, problems during the release of the structure from the mold, e.g., sticking or breaking of the structure, have not been observed. The process is highly reliable: the microstructure is reproduced flawlessly and exhibits a high uniformity across centimetres squared, even at high aspect ratios. The present maximum aspect ratio is approximately 5:1. A minimum feature size of 150 nm is achieved. Both minimum feature size and maximum aspect ratio have not yet been restricted by the mold rather than by the PS\textsubscript{m} process, and therefore the boundaries evolved by the process are still unknown. PS\textsubscript{m} is an easy and cost effective process. A polymer solution is applied on a mold, and brought into contact with a miscible non-solvent. The solvent is preferentially removed in a polymer rich part and a polymer lean part. The polymer rich part solidifies and assimilates the relief structure on the mold. Phase separation is applied for decades in the fabrication of polymer membranes. The mass fabrication of these membranes is performed in roll-to-roll processes, and we anticipate on up scaling of PS\textsubscript{m} in a similar process. Phase separation can yield a porous polymer structure, and therefore PS\textsubscript{m} enables the fabrication of porous microstructures. The possibility to introduce porosity in a microstructure also opens avenues for mass transport through the microstructure, which is an important prerequisite in e.g., tissue engineering. Recently, the fabrication of a simple three-dimensional structure by using PS\textsubscript{m} is demonstrated. The structure originates from the controlled inclusion of air bubbles in the process, and does not require extra processing steps in the PS\textsubscript{m} process. PS\textsubscript{m} combines an easy and cost effective process with a broad range of materials, high reliability and new possibilities. PS\textsubscript{m} therefore complements the present spectrum of micro fabrication techniques well.

Nanoimprint Lithography (NIL) and Dip-pen Lithography are emerging patterning techniques for high-resolution and high-throughput fabrication of semiconductor and optoelectronic chips. Micro-contact pattern transfer techniques have been recently proven useful in cell growth and patterned protein antibodies surface engineering. By using similar non conventional micro/nanofabrication approaches to engineer well-defined high aspect nanostructures in confined environments, it is now possible to control molecular interactions at nanoscales for nucleic acids and proteins testing. We will report new designs of integrated clinical diagnostic platforms to assess likely response to therapy for complex diseases, and in particular for cancers. Applications to pathogens identification, forensic DNA fingerprinting, DNA mapping in nanochannels, near-field aperture fabrication for DNA and protein testing, and nanoparticle arrays fabrication for Rhaman and SERS spectroscopy at the single molecule level will also be reported. A major improvement is the capability of confining electromagnetic field gradients in particular for cancers. Applications to pathogens identification, forensic DNA fingerprinting, DNA mapping in nanochannels, near-field aperture fabrication for DNA and protein testing, and nanoparticle arrays fabrication for Rhaman and SERS spectroscopy at the single molecule level will also be reported. A major improvement is the capability of confining electromagnetic field gradients in
polymeric substrates revealed super-hydrophobic behaviour of nano-pillars which improves spot uniformity, fluorescence signal, while reducing spot size and increasing array density by several orders of magnitude beyond the current limitation. The fabrication of organic optical materials will also be enablers of displays and other flexible polymeric photonic devices that could be integrated into portable medical imagers or biochips combining computing and communications. Hence the development of advanced nanoimprint lithography technologies could impact significantly the areas of genomics, proteomics, drug discovery and emerging molecular clinical diagnostics.

9:00 AM *U6.2
The Special Industrial Application of Thermal Bubble Inkjet Technology, Jen-Ping Hsu, Opto-Electronics & Systems Labs; Printing Technology Division, Industrial Technology Research Institute, Hsinchu, Taiwan.

Inkjet technology is a promised technology for low cost, large area and well-controlled micro dispense. This presentation introduces the special industrial applications including LEP (Light Emitting Polymer). Color Filter, circuit board, high density bio Chip and high flow rate fuel injector. These special industrial applications strongly challenge the capability of Inkjet method, because the working fluidic properties are generally with high viscous, corrosive and low surface tension. To overcome these problems, ITRI developed their self-designed inkjet platform and industrial inkjet head. Thermal bubble inkjet technology was first used to approach LEP printing process. The piezo-electric inkjet technology is an alternative inkjet method. In general, thermal bubble inkjet exhibits thermal degradation and ink incompatibility problem. However, the former has the advantage of low cost and simple control system comparing to the latter. This presentation reveals the feasibility of thermal bubble inkjet used on the LEP device including EL Logo, a 64x64 dot matrix device. In the bio chip application, we demonstrated the specified inkjet head with 200 kinds of fluid which provided high speed dispersed DNA array named "Phalanx Jet Array" technology. Also, the other key issue is the better film profile and printing quality which strongly affected by the substrate treatment and fluid properties. For better control film profile and inkjet process design, the inkjet dynamic simulation tool was developed. This presentation discusses about the limitation and the consideration of the inkjet process by this simulation tool.

9:30 AM *U6.3

Replacing conventional photolithography with simple printing technologies offers inexpensive fabrication of large area thin film transistor (TFT) backplanes, but presents numerous materials processing challenges. The combination of additive and subtractive jet-printing provides flexibility in the choice of materials, within a single printing process. We describe jet-printed fabrication of both amorphous silicon and polymer TFT backplanes on glass and flexible substrates, without using conventional photolithography. A-Si TFT arrays use a series of jet-printed wax mask for subtractive patterning of the TFT array. Once the wax mask is printed, the thin film of metal, dielectric or a-Si, is etched and the mask is removed prior to deposition of the next layer. Accurate registration of layers allows better than 75 dpi pixel resolution, and prototype 128x128 pixel arrays with have been demonstrated, including arrays on flexible substrates made with a low temperature a-Si process. These arrays are completed as image sensors by adding a high fill factor a-Si p-i-n photodiode. The TFT characteristics are excellent, and acquired images in both visible light and x-ray exposure will be presented. The polymer TFT arrays is fabricated using jet-printing for both subtractive and additive patterning. First, the subtractive wax mask digital lithography process is used to define the gate, and source/drain features of the array. Then, additive jet printing provides the patterned polymer depletion that is necessary for achieving semiconductor isolation between transistors in the array. The polythiophene polymer solution is jetted from a piezo-ink-jet head, and the devices exhibit TFT mobility of 0.1 cm²/Vs, on/off ratios of 10⁷, and low bias-stress. There is a high yield of TFTs and a reasonably narrow performance distribution across each array. The array process provides high performance display addressing, and the integration of display media to the backplane will be discussed.

10:30 AM *U6.4
Laser Printing of Micro-Power Sources, M. Ollinger, Center, Naval Surface Warfare Center-Cahlgren Division, Bethesda, Maryland; 'Dept of Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey.

The trend for developing increasingly smaller and more autonomous micro-electronic devices has not yet been matched by power sources with correspondingly reduced volumes. An obvious solution would be to employ micro-power sources comprised of photovoltaics for harvesting power and microbatteries for storing it until it's needed. At NRL we are investigating the fabrication of these micro-power devices using a laser printing technique called laser direct-write. Since it is a rapid prototyping process, the size, geometry and configuration of an individual or an array of micro-power components can easily be changed to accommodate the requirements of a given system. Using this technique, we have fabricated micro-electrochemical power sources, such as primary Zn-Ag₃O and secondary Li-ion microbatteries, in planar and stacked configurations. Preliminary results show capacities over 200 mAh and discharge currents of up to 1 mA for devices with mm² footprints weighing just a few milligrams. The same technique has also been used to produce dye-sensitized photoelectrochemical solar cells. Comparison to other micro-power source fabrication techniques will be discussed as well as implications for powering microdevice and microsensor systems. This work was supported by the Office of Naval Research.

11:00 AM *U6.5
Towards All Organic Electronic Components Circuits - From Diodes, Transistors, to Memory Device. Yang Yang, Department of Materials Science & Engineering, University of California-Los Angeles, Los Angeles, California.

Organic electronics are emerging as a strong field. In this presentation, I will summarize recent progress done at UCLA which will eventually leads toward all organic (plastic) components circuits. We have invented high speed organic diode, high performance organic memory device, organic transistors, and printable circuits. By combing these components, it is possible to build electronic circuits contains all organic electronic components in the near future.