## Biomaterial Interfaces
## Room 2014 - Session BI2-TuM
### Biodiagnostic Innovation

**Moderator:** S. Saavedra, University of Arizona

8:00am **BI2-TuM1 The Fabrication and Characterization of Polycrystalline Silicon Active Layer Thin Film Transistor with Vertically Aligned Carbon Nanofiber***, **J.-W. Park**, S.-J. Jun,* The University of Tennessee*; A.V. Melechko, T.E. McKnight, M.L. Simpson,* Oak Ridge National Laboratory*; P.D. Rack,* The University of Tennessee

Thin film transistors (TFT) with vertically aligned carbon nanofibers (VACNF) are an attractive electronic switching device for nanoscale electroanalysis and delivering biological material into live cells. In our previous work, we have demonstrated an inverted back-channel-etched amorphous silicon TFT array integrated with VACNFs. To enhance the device performance, we have explored a polycrystalline silicon active and n+ contact layer with a standard top-gate structure. For the current device, source/drain and gate metals and gate dielectric thin films were rf magnetron sputter deposited. The Polycrystalline active layer and n+ contact layers were deposited by low pressure chemical vapor deposition (LPCVD). We have examined several enhanced crystallization strategies including stress induced crystallization (SIC) using dielectric caps and metal induced crystallization (MIC). The silicon films have been characterized by x-ray diffraction, scanning electron microscopy, and Raman spectroscopy. In this presentation, we will demonstrate the process flow of the staggered structured polycrystalline TFTs and the nanofiber integration scheme. The electrical characteristics of the transistor will be discussed and correlated to the silicon active layer crystallization. Furthermore, we will demonstrate the electrochemical characteristics of the TFT addressed array in various biological electrolyte solutions.

8:20am **BI2-TuM2 Detection of Surface Potential Modulation Induced by Molecular Dipole Moment for Biosensor Platform Development on GaAs***, **K. Lee**, H. Park, R. Jean,* Purdue University*; A. Yulius,* Yale University*; A. Ivanisevic, J. Woodall, D.B. Janes,* Purdue University

Ultra-sensitive RNA detectors have been receiving enormous attentions with recent breakthroughs in finding RNA biomarkers for specific diseases. One way to detect a small quantity of specific biomarkers is to utilize well-established biological interactions. Generally, there are two key challenges when using bio-molecules as active sensing components: 1) reliable immobilization of bio-molecules and 2) an efficient sensing mechanism to convert a sensing event into a quantifiable signal. In this study, 1-octadecanethiol (ODT) and TAT peptides are self-assembled onto pre-fabricated GaAs-based sensor platforms, and conductivity modulation due to surface potential changes of ODT- or peptide-modified devices will be investigated. The TAT peptides used in this experiment are known to retain their recognition properties with TAR RNA after being attached on a GaAs surface. The sensor layer structure, which consists of a undoped low-temperature grown GaAs cap (3 nm), a 1e20 cm@super -3@ n-GaAs cap (10 nm), a 5e17 cm@super -3@ n-GaAs channel (50 nm), and a 5e16 cm@super -3@ p-GaAs base (100 nm) from the top, was grown by MBE on semi-insulating GaAs. The first two layers are added to achieve non-alloyed ohmic contacts with low specific contact resistivity. Deposition of Au/Ti injector/collector contacts completes the device fabrication, and the I-V curve displays ohmic characteristics with high current density. Subsequent wet-etching of the top cap layer resulted in ~20x decrease in conductivity, which is explained by surface Fermi level pinning of air-exposed GaAs. ODT-modification increased conductivity by ~30%, whereas no significant change was observed with peptide-modification, which could be attributed to either passivation or molecular dipole effect. The dip-pen nanolithography technique is being investigated to increase the surface coverage of sensing molecules on active device regions, and studies on reactivity of modified devices to TAR RNA is still in progress.

8:40am **BI2-TuM3 Covalent Functionalization of Amorphous Carbon Thin Films: Materials Integration for Real-time Electromechanical Biosensing***, **B. Sun**, P. Colavita, H. Kim, M. Marcus, L.M. Smith, R.J. Hamers,* University of Wisconsin at Madison

One of the barriers to real-time biosensing is the need for development of interfaces that are compatible with microelectronics processing methods and that also provide the requisite selectivity and stability when exposed to biological environments. Previous studies have shown that diamond thin films exhibit excellent stability and selectivity. However, diamond deposition temperatures are typically high, limiting the ability to integrate with low-temperature materials. Amorphous carbon films can be deposited to form very thin coatings on a wide variety of materials. Here, we show that varpor-deposited amorphous carbon (a-C) can be covalently modified with functional organic layers in order to covalently tether biomolecules, yielding excellent interfaces with excellent selectivity and stability. We characterized functionalized films by X-ray Photoelectron Spectroscopy (XPS), Infrared Reflection-absorption Spectrocopy (IRRAS), and fluorescence techniques. Surfaces coated with amorphous carbon and covalently modified by single stranded DNA exhibit high biochemical selectivity when exposed to complementary vs. non-complementary sequences. Our results show that covalently modified amorphous carbon films display excellent chemical stability, superior to alternative substrates such as gold, glass, etc. We also demonstrate that the chemical treatments developed here are compatible with metal electrode structures, by integrating amorphous carbon thin films with Quartz Crystal Microbalance (QCM) sensor. We demonstrate real-time DNA detection on the carbon-coated QCM sensor. Moreover, the sensor surface can be regenerated multiple times with no detectable degradation of its performance. Our results demonstrate that amorphous carbon thin film forms a stable bio-interface with excellent microelectronic compatibility, that provides a suitable platform for integrated real-time bio-electrical sensing and existing microelectronic technology.

9:00am **BI2-TuM4 Single Nanopores for the Detection and Characterization of DNA and Anthrax Toxins***, **J.J. Kasianowicz**, B. Nablo, M. Misakian, S.E. Henrickson, K. Rubinson,* NIST*; T. Nguyen, R. Gussio,* NCI*; K.M. Halverson, S. Bavari, R.G. Panchal,* USAMRIID*; V.M. Stanford,* NIST **INVITED**

We are using electrophysiology, molecular biology and computer modeling to better understand how biopolymers (e.g., single-stranded DNA and proteins) partition into and transport through nanometer-scale pores that are formed by bacterial toxins. The results provide insight into the mechanism by which these toxins work in-vivo. They are also the physical basis for several potential nanobiotechnology applications including rapid DNA sequencing, sensitive and selective detection of a wide range of target species, high throughput screening of therapeutic agents against several anthrax toxins, and detection of anthrax lethal toxins in blood. Supported in part by NIST, the NIST Advanced Technology Program, the NIST Office of Law Enforcement Standards, and NSF.

9:40am **BI2-TuM6 A Novel High-Throughput DNA Chip Analysis Platform***, **O. Prucker**, T. Neumann, G. Dame, T. Brandstetter, J. Ruehe,* University of Freiburg - IMTEK, Germany

One of the key problems in the development of a DNA chip for a given analytical problem is the determination of suitable chip parameters: the correct DNA probe sequences need to be found, different types of buffers are to be tested at different buffer concentrations and the optimum temperatures for, both, hybridization and melting need to be determined. This list is by no means exhaustive but already demonstrates that the development and optimization of a chip requires thousands of experiments and test chips leading to often unacceptable development times and costs. In this contribution we will present a chip analysis platform technique that addresses this problem. The entire system consists of two key features: A total internal reflectance fluorescence (TIRF) readout system in which the fluorescence is excited through the chip itself which acts as a waveguide. The exciting light is such provided through the evanscent wave travelling along the chip surface. This mode of excitation allows for the fluorescence readout in the presence of the analyte solution and a flow cell with heating / cooling devices can be used to follow the hybridization and to reset the chip by melting/washing protocols without the need to take the chip out of the detector. The second key feature of this system is the chip itself. We have developed a polymer chip made from PMMA or cyclic olefin copolymers (COCs) onto which the probes are printed together with a photocrosslinkable polymer. Upon illumination the polymer forms a three dimensional hydrogel that acts as a carrier for the probes. This "skyscraper" approach allows for the deposition of a higher probe concentration per surface area leading to an enhanced chip sensitivity and selectivity. Examples will be given that demonstrate that most of the parameters that are essential for chip performance can be determined on one single chip such that most questions are answered "at the end of the day".

10:40am **BI2-TuM9 Biosensing with Fluidic Force Discrimination and Microbead Labels: Comparison of Sequential and Mixed-Homogeneous Assay Schemes*, S.P. Mulvaney*,** *K.M. Myers, L.J. Whitman,* Naval Research Laboratory

A significant challenge for all biosensors is to achieve high sensitivity and specificity while minimizing sample preparation requirements, protocol complexity, and assay time. We have achieved multiplexed, femtomolar detection of both DNA and proteins in complex matrices in minutes by labeling conventional assay schemes with micrometer-scale beads, and applying fluidic force discrimination (FFD). In such assays, analytes captured onto a microarray are labeled with microbeads, and nonspecifically bound bead labels are preferentially removed through the application of controlled microfluidic forces. The density of beads that remain bound is proportional to the analyte concentration. Our typical microbead-labeled assay uses a sequential scheme, whereby the biorecognition builds from the capture probe, to the target, to the label probe, and finally the bead label. Alternatively, a two-step mixed-homogeneous assay scheme is possible with microbead labels and FFD. In this scheme, the sample is mixed with all the reagents (including the microbeads) in solution, and the analyte-loaded beads are then allowed to interact with the capture probes on the microarray. In the second step, FFD is applied and the bound labels counted. This scheme holds potential for enhanced target capture via preconcentration, but the large relative size of the microbead label relative to the molecular analytes complicates the biophysics. Our analysis of the sequential vs. mixed-homogeneous assay schemes at high and low analyte concentrations will be discussed. @FootnoteText@ S.P.M. and K.M.M. are employees of Nova Research Inc., Alexandria, Va.

11:00am **BI2-TuM10 HaloTag@super TM@ Technology for Protein Arrays*, N. Nath*,** *J. Zhu, D. Klaubert, D. Storts, K. Wood,* Promega Corporation

Protein interaction arrays are emerging tools geared toward proteome scale detection of protein-protein, protein-drug or protein-DNA interactions. Wide application of protein array technology however faces significant challenge due to lack of high-throughput method for protein expression and purification. Here we present a new HaloTag@SUPER TM@ technology for rapid and covalent capture of fusion proteins in an oriented fashion directly from complex protein matrices without any prior purification. HaloTag protein is a mutant hydrolase that makes covalent bonds with its chloroalkane substrate. We demonstrate that proteins expressed as HaloTag fusions can be sensitively and irreversibly captured on a PEG based microarray substrate modified with chloroalkane substrate. Because HaloTag is compatible with in-vitro protein expression systems, multiple fusion proteins can be rapidly synthesized (90min) and immobilized in parallel. We also demonstrate that captured fusion proteins are functionally active and are able to interact with their interacting partner. Result indicates that HaloTag technology is perfectly suited for rapid prototyping of protein interaction arrays for large scale study of interaction networks.

11:20am **BI2-TuM11 Partial Hydrolysis of a Polyimide Surface for Biomolecule Immobilization and Biosensing*, S. Chakraborty*,** *P. Betala, W.J. Buttner, V.H. Perez-Luna, J.R. Stetter,* Illinois Institute of Technology

The unique electrical, thermal, chemical and mechanical properties of polyimide films make them widely used in electronic components. Thus, their surface modification could be of interest in the biosensors field. Here we present a detailed study on the surface modification of polyimide films through partial hydrolysis. The surface modification is explored by wettability measurements and Fourier Transform Infrared (FTIR) Spectroscopy. Strategies to immobilize biomolecules such as antibodies on these surfaces are presented. Immobilization strategies take advantage of the carboxyl groups formed during the hydrolysis procedure. The application of this process to biosensing is illustrated with an impedance based imaging system array that is adapted to the detection of biological entities.

11:40am **BI2-TuM12 Label-Free Biosensing in Array Format Utilizing Surface-Adsorbed Core-Shell Nanoparticle Layers*, R. Dahint*,** *E. Trileva, H. Acunman, U. Konrad, M. Zimmer,* University of Heidelberg, Germany*; V. Stadler,* German Cancer Research Center, Germany*; M. Himmelhaus,* University of Heidelberg, Germany

A novel method for spatially resolved, label-free biosensing based on core-shell nanoparticle films is presented. For the preparation of the layers, polystyrene particles of 350 nm in diameter are self-assembled on a gold-coated substrate to form a random-close-packed monolayer. Afterwards, the nanoparticle layer is covered with a metal film by first depositing gold colloid of 2-3 nm in size, followed by an electroless plating step. The resulting surface shows a pronounced optical extinction upon reflection of white light with the extinction maximum located in the NIR region of the electromagnetic spectrum. When organic molecules bind to the surface, the peak position of this maximum shows a pronounced red-shift. In case of octadecanethiol adsorption, a peak shift of 55 nm on average has been observed, which is about five times that of established label-free sensing methods based on propagating and localized surface plasmons. By immobilizing a pattern of different peptides on the nanoparticle layers and reacting the surface with specific antibodies it has been demonstrated that biospecific interactions can be label-free detected in array formats with high sensitivity. For the suppression of non-specific adsorption, which may lead to false results in the identification of binding events, the peptides have been embedded into an inert matrix material based on poly(ethylene glycol). In the future we intend to immobilize high-density peptide libraries onto the nanoparticle layers by combinatorial synthesis to facilitate in situ, parallel, time-resolved, and label-free screening of biospecific binding processes.

12:00pm **BI2-TuM13 Towards a Label-Free Biosensor: Defining and Measuring Sensitivity of Nanoscale Plasmonic Systems*, G. Nusz*,** *A. Curry, A. Wax, A. Chilkoti,* Duke University

A label-free biosensor based on the optical response of the surface plasmon resonance of nanostructures (nanoSPR) is proposed. This system transduces nanoscopic changes in refractive index near the nanostructure surfaces into a macroscopically measureable signal. The sensor is designed such that binding of the target biomolecule to the metal nanostructure effects this refractive index change, generating the signal. Here, we present our work on optimizing the nanostructures to create the most useful biosensing system. We examine possible routes towards optimizing sensor sensitivity with an emphasis towards design considerations such as nanostructure synthesis, detection method, analyte structure and system applicability to biological samples. Specifically, we present our analysis of single-nanoparticle spectroscopy of both chemically synthesized and electron beam lithographically fabricated arrays of single and near-field coupled structures. We define and analyze sensitivity of nanostructures in terms of refractive index sensitivity, electric field enhancement and model binding studies. With these assays, it is possible to form a more complete characterization of nanoparticles in general and to determine of optimal nanoparticle characteristics for biosensors.

# Author Index

## Bold page numbers indicate presenter

— A —
Acunman, H.: BI2-TuM12, 2
— B —
Bavari, S.: BI2-TuM4, 1
Betala, P.: BI2-TuM11, 2
Brandstetter, T.: BI2-TuM6, 1
Buttner, W.J.: BI2-TuM11, 2
— C —
Chakraborty, S.: BI2-TuM11, **2**
Chilkoti, A.: BI2-TuM13, 2
Colavita, P.: BI2-TuM3, 1
Curry, A.: BI2-TuM13, 2
— D —
Dahint, R.: BI2-TuM12, **2**
Dame, G.: BI2-TuM6, 1
— G —
Gussio, R.: BI2-TuM4, 1
— H —
Halverson, K.M.: BI2-TuM4, 1
Hamers, R.J.: BI2-TuM3, 1
Henrickson, S.E.: BI2-TuM4, 1
Himmelhaus, M.: BI2-TuM12, 2
— I —
Ivanisevic, A.: BI2-TuM2, 1
— J —
Janes, D.B.: BI2-TuM2, 1
Jean, R.: BI2-TuM2, 1
Jun, S.-J.: BI2-TuM1, 1
— K —
Kasianowicz, J.J.: BI2-TuM4, **1**
Kim, H.: BI2-TuM3, 1
Klaubert, D.: BI2-TuM10, 2
Konrad, U.: BI2-TuM12, 2
— L —
Lee, K.: BI2-TuM2, **1**
— M —
Marcus, M.: BI2-TuM3, 1
McKnight, T.E.: BI2-TuM1, 1
Melechko, A.V.: BI2-TuM1, 1
Misakian, M.: BI2-TuM4, 1
Mulvaney, S.P.: BI2-TuM9, **2**
Myers, K.M.: BI2-TuM9, 2
— N —
Nablo, B.: BI2-TuM4, 1
Nath, N.: BI2-TuM10, **2**
Neumann, T.: BI2-TuM6, 1
Nguyen, T.: BI2-TuM4, 1
Nusz, G.: BI2-TuM13, **2**
— P —
Panchal, R.G.: BI2-TuM4, 1
Park, H.: BI2-TuM2, 1
Park, J.-W.: BI2-TuM1, **1**
Perez-Luna, V.H.: BI2-TuM11, 2
Prucker, O.: BI2-TuM6, **1**
— R —
Rack, P.D.: BI2-TuM1, 1
Rubinson, K.: BI2-TuM4, 1
Ruehe, J.: BI2-TuM6, 1
— S —
Simpson, M.L.: BI2-TuM1, 1
Smith, L.M.: BI2-TuM3, 1
Stadler, V.: BI2-TuM12, 2
Stanford, V.M.: BI2-TuM4, 1
Stetter, J.R.: BI2-TuM11, 2
Storts, D.: BI2-TuM10, 2
Sun, B.: BI2-TuM3, **1**
— T —
Trileva, E.: BI2-TuM12, 2
— W —
Wax, A.: BI2-TuM13, 2
Whitman, L.J.: BI2-TuM9, 2
Wood, K.: BI2-TuM10, 2
Woodall, J.: BI2-TuM2, 1
— Y —
Yulius, A.: BI2-TuM2, 1
— Z —
Zhu, J.: BI2-TuM10, 2
Zimmer, M.: BI2-TuM12, 2