## Biomaterial Interfaces
## Room 311 - Session BI-ThA

## Bionanotechnology
**Moderator:** T.P. Beebe, University of Delaware

2:00pm **BI-ThA1 Strategies to Increase the Sensitivity of Biosensors based on the Light Absorption of Immobilized Metal Nanostructures**, ***F. Frederix,*** *K. Bonroy,* IMEC, Belgium*; D. Saerens,* VUB, Belgium*; G. Maes,* KULeuven, Belgium*; S. Muyldermans,* VUB, Belgium*; G. Borghs,* IMEC, Belgium

The Transmission Plasmon Biosensor is a novel, cheap and easy-to-handle biosensing technique. It consists of immobilized metal nanoparticles that exhibit plasmon absorption peaks. This absorption is highly dependent on the size, the shape and the dielectric properties of the close environment of these nanoparticles and can therefore be used to perform biosensing. The nanoparticle films were realized using self-assembly techniques, thermal evaporation, electroless plating or soft-lithographic techniques. Mixed SAMs were used to couple antibodies to the nanoparticle films. The change in absorption properties of the nanoparticle films upon antibody-antigen binding was monitored in order to obtain quantitative information on the antibody-antigen interaction (prostate specific antigen). Besides the localised plasmon resonance sensing, we observed a novel physical phenomenon namely the intraband transition absorption enhanced sensing. Furthermore, the applied technique was identified to be a useful alternative for the most widely used clinical immunosensing technique, i.e. the ELISA technique. This promising alternative was applied onto modified microtitre plates, which allow for the implementation into an array technology. The Transmission Plasmon Biosensor fulfils therefore the needs of an ideal, multi-analyte bio(nano)sensor. However, the sensitivity could be a drawback of this sensing technique. We will show several strategies to increase the sensitivity to a diagnostically interesting concentration range (ng/mL range). These strategies will involve the use of camel antibodies to sense closer to the sensor surface (the sensitivity decreases exponentially away from the surface), the use of multiple nanoparticle films and nanoparticles with special morphologies. In addition, we will show that this sensing technique can be also applied for performing enzyme sensing and that it showed remarkable results for small molecule detection (antibiotics).

2:20pm **BI-ThA2 Impact of Composite Shell Thickness on Stability of Single Enzyme Nanoparticles**, ***A.S. Lea****, J.B. Kim, J.W. Grate,* Pacific Northwest National Laboratory

Single-enzyme nanoparticles (SENs), comprised of individual alpha-chymotrypsin molecules surrounded by a porous organic/inorganic composite network less than a few nanometers thick, have been developed. The synthetic procedure, entailing enzyme modification and two orthogonal polymerization steps, yields nanoparticles containing a single enzyme. In stability experiments, the incorporation of these enzymes into the nanostructure dramatically increased its enzymatic stability. Furthermore, the nanoscale structure around the enzyme is sufficiently thin and porous that it does not impose a significant mass transfer limitation on the substrate. We have used tapping mode AFM (TM-AFM) to characterize single enzyme nanoparticles containing alpha-chymotrypsin (SEN-CT). Compared to transmission electron microscopy (TEM), TM-AFM resulted in much quicker and more accurate characterization of SENs since they are still in a hydrated state. We can tailor the thickness of the composite shell during the orthogonal polymerization steps in the synthesis of the SENs. The measured size-distribution of the different preparations was used to relate enzyme stability to the thickness of the porous composite shell. We will discuss this relationship in detail.

2:40pm **BI-ThA3 Vertically Aligned Carbon Nanofiber Array Integrated with Active-Addressed Thin Film Transistors for Intra/Extracellular Stimulus and Measurement**, ***S.-I. Jun****, P.D. Rack,* The University of Tennessee*; T. McKnight, A.V. Melechko, M.L. Simpson,* Oak Ridge National Laboratory

Vertically aligned carbon nanofibers (VACNF) have been used as nanoscaled electrodes for electroanalysis and as nanostructured scaffolds for delivering biological material into live cells. Thin film transistors (TFTs) have long demonstrated their effectiveness for driving, switching, and read-out capabilities in many microelectronic applications. In this study, we have fabricated and characterized a 20X20 active matrix thin film transistor array with integrated vertically aligned carbon nanofibers grown from Ni catalyst by direct current plasma enhanced chemical vapor deposition (DC-PECVD). This integrated device provides great potential to perform direct cell sensing, probing, and recording with a high electrode density and active addressing. Consequently, actively addressed nanofiber arrays can offer bi-directional interfacing with tissue matrices using intercellular positioning of electrode elements as well as the potential for intracellular residence of probes within individual cells. For this device, each film in the TFT array was fabricated by an rf magnetron sputtering process with DC substrate bias at a substrate temperature below 200°C. In this presentation, we will demonstrate the process flow of the inverted metal-oxide-semiconductor field effect transistor and the nanofiber integration scheme. The electrical characteristics of the transistor will be discussed and the electrochemical characteristics of the TFT addressed array in various biological electrolyte solutions will be presented.

3:00pm **BI-ThA4 Dynamic Surface Modification and Patterning using Electrochemistry and Molecular Assembly Approach**, ***C.S. Tang****,* Swiss Federal Laboratories for Materials Testing and Research (EMPA), Switzerland*; S. Makohliso, M. Heuschkel,* Ayanda Biosystems SA*; J. Voeroes, S. Sharma,* Swiss Federal Institute of Technology (ETH)*; B. Keller,* Swiss Federal Laboratories for Materials Testing and Research (EMPA), Switzerland*; M. Textor,* Swiss Federal Institute of Technology (ETH)

Microarray technology is a powerful and versatile tool commonly used in biochemistry and molecular biology. This miniaturized and parallelized technique has contributed significantly to bioanalytical processes such as large-scale genomic sequencing. One option for additional flexibility within a microarray is the use of electrochemical tools to dynamically influence and steer formation and properties of adsorbed molecular layers at the solid-liquid interface. By controlling and manipulating the placement of polyelectrolytes and biomolecules under the influence of an electric field, we have demonstrated that an electroactive biosensing platform with specificity and high sensitivity enable rapid screening and discrimination of different biomolecules with high selectivity. Using patterned substrates consisting of conductive areas in a non-conductive background, the electrically switchable surface can be modified to reversibly adsorb and release an adlayer of protein-resistant polymer. Macromolecules or biomolecules could be subsequently adsorbed onto the polarized indium tin oxide (ITO) microelectrodes by using simple surface chemistry. As a proof of concept, labeled functionalized polymer, proteins and vesicles were immobilized onto the ITO microelectrodes to produce a highly selective and heterogeneous microarray with specific electronic addressability. Some future applications with a localized addressable electronic microarray could include microfluidics, biosensors, drug delivery and manipulation of cellular neuron network for tissue engineering.

3:20pm **BI-ThA5 Fabrication of Bioconjugated Polymeric Nanostructures and Metal Nanowires by AFM Anodization Lithography**, *W.-K. Lee, H. Ma, S. Chen, A. Chilkoti,* ***S. Zauscher****,* Duke University

Patterning of polymeric and biomolecular nanostructures on surfaces and the control of their architecture are critically important for the fabrication of biomolecular devices and sensors. Here we show for the first time how we use AFM anodization lithography to chemically modify polymer brushes directly to allow conjugation of biomolecules. Surface-confined non-fouling and protein resistant poly(oligo(ethylene glycol) methyl methacrylate) (pOEGMA) brushes were prepared on silicon substrates by surface-initiated atom transfer radical polymerization (ATRP) in a grafting-from approach. These pOEGMA brushes were then patterned directly on the nanoscale by AFM anodization lithography, generating nano-trenches with carboxylic acid functionality. Proteins were then immobilized on these nanopatterned areas by suitable coupling chemistries. We also show an intriguing approach to deposit gold onto silicon oxide patterns by field-emission from gold-coated AFM probes. We capitalize on this novel lithography approach to fabricate gold nanowires of arbitrary shape. Our unique nanofabrication approaches lead to novel types of nanostructures that can potentially be used as biosensors or as substrates for the precise presentation of biomolecular queues to cells. Furthermore, our gold nanostructures can be used for electrical connections, or as plasmonic structures for biomolecular sensing.

3:40pm **BI-ThA6 In-situ Microcontact Printing of Proteins**, ***D. Mayer****, D. Schwaab, O. Salomon, A. Offenhaeusser,* Research Center Juelich, Germany*; A. Yasuda, J. Wessels,* Sony International (Europe) GmbH, Germany

Soft lithography appears to be a promising candidate among other techniques like electron beam-, ion beam- or x-ray lithography, in order to define structures below 100 nm. In contrast to the others, soft lithography has the advantage of being a relatively simple low costs technique. In

addition, the technique can in principle be applied for large areas and therefore provides a fast lithography process. Furthermore soft lithography is fully chemical and bio-compatible. The main objective of the presented work is to establish a powerful technique in order to transfer biomolecules to functional surfaces with structure size beyond the limit of photolithography. On this account we have developed a novel in-situ approach for the patterned transfer of proteins. The proposed technique is a modification of the commonly used Microcontact Printing (@mu@CP). The main derivative is that all transfer steps are performed under physiological conditions. For testing the capabilities of in-situ Microcontact Printing we have used horse heart cytochrome c (cyt c) as model molecule. Electrochemical investigations were performed to compare the conventional and the new in-situ @mu@CP method by measuring the redox activity of cyt c transferred with different techniques. We succeeded to print proteins under conservation of their structural integrity and functionality, while the activity of molecules transferred with conventional @mu@CP is much lower. In addition we will demonstrate by means of surface scanning microscopy methods that this technique is also capable of transfer patterns with a critical dimension of 150nm.

4:00pm **BI-ThA7 Microfluidic Neuronal Culture Device for Neuroscience Research**, ***N.L. Jeon,*** University of California, Irvine **INVITED**

This presentation will describe a novel microfabricated neuronal culture device and its application in Alzheimerâ?Ts Disease and Axonal Regeneration research. The device combines microfabrication and surface micropatterning approaches to create a multi-compartment neuronal culturing platform that can be used in a number of neuroscience applications. A replica-molded PDMS is placed on a tissue culture dish (polystyrene) forming two or more fluidically isolated compartments. These compartments are separated by a physical barrier in which a number of micron-size grooves are embedded to allow growth of neurites across the barriers while maintaining fluidic isolation. Cells are plated into the somal (cell body) compartment and after 3-4 days, axons extend into the adjacent compartment via the grooves. We have successfully used this device to culture primary rat cortical and hippocampal neurons for upto 3 weeks. We demonstrate the ability to maintain fluidically isolated compartment and, thus, expose localized areas of neurons to insults applied in soluble form. We also use microfluidics-compatible surface micropatterning approach to facilitate identification and visualization of neurons. The ability to direct sites of neuronal attachment and orientation of axon outgrowth by micropatterning techniques, combined with fluidically isolated compartments within the culture area offer significant advantages over standard open culture methods and other conventional methods for manipulating distinct neuronal microenvironments.

4:40pm **BI-ThA9 Investigations About the Formation of Supported Phospholipid Bilayers on Structured Surfaces**, ***B. Seantier,*** *I. Pfeiffer, M. Zaech, D. Sutherland,* Chalmers University of Technology, Sweden

There has been a strong current interest in the interaction of lipid vesicles with different homogenous materials surfaces. A number of mechanisms have been discussed leading to the formation of Supported Phospholipid Bilayers (SPBs) (for example on flat SiO@sub 2@) or intact vesicles (for example on flat Au). In our study, we have utilized lithographically defined nanoscale patterns to investigate the role of local variations in surface topography and chemistry on vesicle-surface interaction. We have studied surfaces combining two chemistries (SiO@sub 2@ and Au) where the domain sizes are similar to or below the characteristic size of the vesicles. The mechanism of the SPB formation has been studied by varying parameters such as phospholipids composition, vesicles size and concentration, and the ionic strength of the buffer solution. Quartz Crystals sensor surfaces were structured using dispersed colloidal monolayer masks (d=100nm) and lift off pattern transfer giving pits with combinations of upper and lower surface (~20% of the total surface area) chemistries. 100 nm and 200 nm extruded vesicles of POPC and DMPC have been used to form SPBs (vesicle conc. range varied between 50 μM and 500 μM with and without CaCl@sub 2@). Parallel experiments with identical surfaces utilized Quartz Crystal Microbalance with Dissipation monitoring technique and the Atomic Force Microscopy technique providing time-lapse images of the SPBs formation. The results show a two step mechanism, different from the classical SPB formation, which cannot be explained by the superposition of the vesicle behavior on Au and SiO@sub 2@ surfaces. A complex mechanism involving trapping vesicles in holes and SPB formation at the pits is assumed. In the future perspectives, the size and the shape of the Au pits will be varied. This study should allow us to better understand the influence of the surface topography and chemistry on the SPB formation.

5:00pm **BI-ThA10 Bionanodevices Integrating Biomolecular Motors**, ***R. Tucker,*** University of Florida*; S. Ramachandran, D. Wu, T. Nitta,* University of Washington*; H. Hess,* University of Florida

Biomolecular motors have the ability to convert chemical energy into mechanical work with high efficiency, and can be used to integrate active movement and actuation into hybrid micro- and nanodevices. Recent improvements in the design of nanoscale transport systems (molecular shuttles) based on the motor protein kinesin will be discussed. We will focus in particular on the selective capture of target analytes by the transporters, and on improving the control over motor activation. An investigation into the origins of velocity dispersion of molecular shuttles traveling in channels permitted us to compare sample dispersion occurring in this novel mechanism of transporting samples with established transport methods, such as pressure-driven fluid flow or electroosmotic flow. Applications for biomolecular motor-based devices can be found in a variety of biosensing scenarios.

# Author Index

## Bold page numbers indicate presenter