Nanometer-scale Science and Technology
Room 2016 - Session NS+BI-ThM

Biological and Molecular Applications of Nanoscale Structures

Moderator: H.G. Craighead, Cornell University

8:00am **NS+BI-ThM1 A Nanometer-scale Gene Chip: Detecting Single Molecules of DNA using a Silicon Nanopore**, ***G.L. Timp,*** Beckman Institute **INVITED**

We describe a prospective strategy for reading the encyclopedic information encoded in the genome: using a nanopore in a membrane formed from an MOS-capacitor to sense the charge distribution in a single molecule of DNA. In principle, as DNA permeates the capacitor-membrane through the pore, the electrostatic charge distribution polarizes the capacitor and induces a voltage on the electrodes that can be measured. The sub-nanometer precision available through silicon nanotechnology facilitates the fabrication of this nanometer-scale gene chip, and molecular dynamics provides us with a means to design it and analyze the experimental outcomes. Double-stranded DNA is a highly charged, unusually stiff polymer. And so, the nano-electromechanics of the molecule profoundly affect the design of this detector. Consequently, we have explored the electromechanical properties of DNA using an electric field to force single molecules through synthetic nanopores in ultra-thin silicon membranes. At low electric fields E =@0.5nm, while double-stranded DNA only permeates pores with a radius @>=@1.5nm because the diameter of the double helix is about 2nm. For pores

8:40am **NS+BI-ThM3 Single DNA Molecules Stretched in Electrospun Polymer Fibers**, ***L.M. Bellan***, *J.D. Cross, E.A. Strychalski, J.M. Moran-Mirabal, H.G. Craighead,* Cornell University

We have deposited electrospun polyethylene oxide (PEO) fibers containing isolated single stretched DNA molecules. The ability to stretch single molecules of DNA is desirable for single-molecule sequencing techniques and also allows the study of the behavior of DNA molecules undergoing various forces. Electrospinning is a popular technique for quickly and easily depositing micro- and nanoscale diameter fibers from a variety of materials, and has recently been used in several studies as a method for assembling nanoscale particles and molecules. In the present study, a dilute concentration of fluorescently labeled lambda phage DNA molecules was added to the water solvent used to mix the PEO electrospinning solution. The solution was used to produce isolated nanofibers using the scanned electrospinning technique. The DNA molecules were stretched in-flight in the electrospinning jet and remained stretched when the fluid jet solidified into fibers. These fibers were deposited on coverslips and imaged using fluorescence microscopy. The embedded DNA molecules were seen as single lines of fluorescence ranging from under 3 microns to 19 microns, which is the extended length of the lambda DNA molecule at the base pair to dye labeling ratio used. The variation in length is thought to be due to variations in the electrospinning jet fluid dynamics. By tuning the process parameters we were able to obtain a distribution of stretched lengths with a mode of ~7 microns. We also observed chain scission in some cases. Given the long relaxation time of DNA in the polymer solution and the high strain rates present in electrospinning jets, both stretching and sporadic chain scission are expected. Current work is focused on mechanical manipulation of the resulting fibers and DNA molecules embedded therein.

9:00am **NS+BI-ThM4 Polypyrrole Based Nano-Electrode Arrays Produced by Colloidal Lithography**, ***P. Lisboa***, *A. Valsesia, P. Colpo, F. Rossi,* European Commission, Institute of Health and Consumer Protection, Italy

The implementation of sensor platforms providing high sensitivity of detection is a crucial step for the design of the new analytical device generation for biosensor developments. Electrochemical sensors have shown a high potential for this challenge. A drastic increase of sensitivity of bio-event detection@footnote 1@ has been proven by designing platform with active/non-actives region at nanoscale. Besides, the electrochemical sensitivity can be as well enhanced by using nano-electrode arrays that increase mass transport rate.@footnote 2@ Polypyrrole (PPy) is a good candidate to fulfil these requirements. Its preferential material for bio-analytical electrochemistry based sensor thanks to its excellent biocompatibility and higher conductivity, together with the possibility of being functionalised with biological relevant functional groups.@footnote 3@ In this work PPy nano pillars were fabricated by electrochemically growing PPy in a nano-template of gold nano-seeds produced by colloidal lithography. Atomic force Microscopy and Scanning Kelvin Microscopy demonstrated that PPy grown only inside the conductive gold seeds, creating conductive nano pillars surrounded by an insulating material. The nano-structured surfaces were studied by Cyclic Voltammetry using hexacyanoferrate and the typical sigmoidal shape voltammogram of nanoelectrodes was obtained.@footnote 2@ The nanoelectrode character of the surfaces is a promising feature to improve the already high sensitivity of biosensors based in nanostructured surfaces. The functionalisation of the nano pillars with bio-active chemical functions gives the possibility of protein immobilization in specific nano-areas which is promising for the production of an array of nano-sensors. @FootnoteText@ @footnote 1@A. Valsesia, P. Colpo, P. Lisboa, M. Lejeune, T. Meziani, F. Rossi, Langmuir 2006, 22, 1763.@footnote 2@D.Arrigan, The Analyst, 2004, 129, 1157.@footnote 3@P. Lisboa, D. Gilliland, G. Ceccone, A. Valsesia, F. Rossi, Applied Surface Science 2005, In Press.

9:20am **NS+BI-ThM5 Biofunctionalized Nanoshells for Biological Detection**, ***J.E. Van Nostrand***, Air Force Research Lab*; C.S. Levin,* Rice University*; J.M. Slocik,* Air Force Research Lab*; J.D. Hartgerink, N.J. Halas,* Rice University*; M.P. Kadakia,* Wright State University*; R.R. Naik,* Air Force Research Lab

The ability to detect chemical and biological agents is arguably one of the highest priority technical challenges today. The capability to obtain specific information at and near single-molecule resolution is the ultimate goal in chemical detection. Recent advances in surface-enhanced spectroscopy have demonstrated that Surface Enhanced Raman Scattering (SERS) displays spectrum enhancements of several order of magnitude when molecules are absorbed onto metallic surfaces. Metallic nanostructures because of their plasmonic properties are attractive SERS substrates, in particular, nanoshells and nanorods. Combining the specificity of biomolecular recognition with these nanostructures might lead to increased sensitivity and selectivity. Localization of biological recognition motifs to the surface of these nanostructures will lead to large signal enhancements when bound to its target. Nanoshells will be functionalized with capture elements (peptide ligands and antibodies) and these biofunctionalized nanoshells will be tested for their ability to detect micoroganisms using SERS.

9:40am **NS+BI-ThM6 Characterization of Silver Nanoparticles Films for the Development of TPB Biosensors**, ***J. Wolstenholme***, Thermo Electron Corporation, UK*; K. Bonroy, G. Borghs, F. Frederix,* IMEC, Belgium*; R.G. White,* Thermo Electron Corporation, UK

Metal nanoparticle films have been subject of much research, primarily due to their interesting optical and electronic properties and due to their high surface-to-volume ratio. According to numerous studies, nanoparticle films are promising as precursors for metallic films, as catalysts and especially as sensing substrates for the development of novel biosensors such as the Transmission Plasmon Biosensor (TPB). This type of biosensor is based upon the optical properties of silver and gold nanoparticles which are used to sense the specific target molecules in a complex matrix. Hereby, the nanoparticles are to be functionalized with self-assembled monolayers (SAMs) of thiols or disulfide molecules. These monolayers form a covalent bond with the gold or silver surface and can have appropriate functional groups to allow the attachment of specific bioreceptors. For surface plasmon based biosensors such as TPB, gold nanoparticles are most frequently used due to their chemical stability and their relatively simple preparation. Nevertheless, various studies and models predict a much higher sensitivity using silver nanoparticles as TPB sensing substrate. However, at this moment the drawbacks for using silver films as sensing substrates are their instability due to the formation of an oxide layer. The latter will negatively influence the formation of well-organized SAMs of thiols and the subsequent functionalization of the particles with specific bioreceptors. In this paper, we describe the FTIR, the XPS and angle resolved XPS characterization of the multilayered TPB sensing substrates, comprising quartz, silanes, silver nanoparticles and thiol molecules. In this study, we compared the thickness of the silane layer, the oxidation ratio of the silver films and the density of the thiol SAM for both silver nanoparticle films and continuous silver films. Our study indicates that the deposition of SAMs decreases the formation of oxides on the silver nanoparticle films.

10:40am **NS+BI-ThM9 Surface Nanostructuring using Colloidal Particles for Improved Biocompatibility**, ***C.J. Nonckreman***, *P.G. Rouxhet, Ch.C. Dupont-Gillain,* Université Catholique de Louvain, Belgium

Nanostructured surfaces offer new perspectives in different fields of application, including the design of biomaterials (implants, catheters, blood

bags). The aim of this work is to create model surfaces presenting bimodal roughness characteristics (scales of 500 nm and 50 nm) using colloidal lithography. An appropriately designed nanoroughness is expected to modulate the effect of the surface chemical composition for controlling the interactions of cells and tissues with materials. Colloidal lithography was performed using adsorption of cationic polymers and adhesion of negatively charged colloidal particles. Polyallylamine hydrochloride was used to confer a positive charge to a glass substrate. On this conditioned surface, a layer of colloids (polystyrene latex) was formed owing to electrostatic attraction. Sequential steps of polycation adsorption and particle adhesion were applied on the substrate, which was then analyzed by scanning electron microscopy. Adjustment of conditions for incubation solutions (concentration, pH and ionic strength), rinsing and drying were tested in order to produce a high surface coverage with colloids and to minimize their aggregation. Thereby, a range of surface structures was obtained: layer of particles with a diameter of 470 nm, layer of particles with a diameter of 65 nm, bimodal roughness made by particles with a diameter of 65 nm on the top of particles with a diameter of 470 nm. The obtained surfaces are conditioned by adsorption of compounds which make them protein repellent, in particular Pluronic F68, a block copolymer of polypropylene oxide and polyethylene oxide. The surfaces finally obtained are being tested with respect to plasma protein adsorption, in particular competitive adsorption of fibrinogen and albumin, and to biocompatibility.

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