Friday Morning, November 7, 2003

Nanometer Structures
Room 317 - Session NS+BI-FrM

Nanotechnology and Biology

Moderator: R.J. Hamers, University of Wisconsin-Madison

9:40am **NS+BI-FrM5 Interaction of Fluorescent Molecules with Metallic Nanoparticles Mediated by Biospecific Interactions**, ***V.H. Perez-Luna***, *K. Aslan, I. Severcan,* Illinois Institute of Technology

Metallic nanoparticles affect the emission characteristics of fluorophores located in their proximity. Here we exploit this strong influence in a system where gold nanoparticles are functionalized with biotin. Preparation of biotinylated gold nanoparticles is performed in the present of a nonionic surfactant to ensure their stability. The interaction of these biotinylated gold nanoparticles with Alexa488-labeled anti-biotin in solution was studied by optical absorption spectroscopy and fluorescence spectroscopy. It was found that reduction or enhancement of fluorescence emission could result when Alexa488-labeled anti-biotin interacted with biotinylated gold nanoparticles. This depended on the surface coverage of biotin groups, the concentration of antibody and the concentration of biotinylated gold nanoparticles. Introduction of soluble biotin to dissociate the bound antibodies from the surface of the nanoparticles reversed the signals observed previously. These observations can be explained in terms of the competing effects that metallic nanoparticles can have on emission of fluorescence. Quenching of fluorescence can occur when the fluorophores are in close proximity to the metallic surfaces. However, metallic nanoparticles can also enhance the excitation intensity due to concentration of the incident field in the vicinity of the nanoparticles. Additionally, metallic surfaces can also provide additional pathways for radiative decay of the fluorophores. These concepts will have important implications for novel materials in fluorescence detection.

10:00am **NS+BI-FrM6 Real-Time, Label Free Biosensing using Immobilized Gold Nanoparticles: Influence of Nanoparticle Size on Sensor Performance**, ***N. Nath***, *A. Chilkoti,* Duke University

We recently demonstrated a label-free optical sensor to quantify biomolecular interactions in real-time that exploits the surface plasmon resonance effect exhibited by noble metal nanoparticles (nanoSPR). The sensor monitors changes in the extinction spectrum of a monolayer of gold nanoparticles on glass as a function of biomolecular binding. We have previously shown that 13 nm diameter gold nanoparticles can monitor the binding of streptavidin to biotin with a detection limit of 16nM. The performance of the biosensor is controlled by the size, shape and dielectric constant of the metal nanostuctures, and their interparticle spacing. As a first towards optimization of the nanoSPR sensor, we investigated the size of gold nanoparticles on sensor performance. Monodisperse gold nanoparticles were chemically synthesized with diameters ranging from 12 nm to 50 nm. The extinction spectrum of the monolayers of gold nanoparticles of all sizes exhibited both a red shift as well as an increase in the extinction at peak wavelength as a function of bulk solution refractive index. However, sensitivity, defined as change in extinction per unit change in bulk refractive index, increases with an increase in particle size and reaches a maximum value of 1.42 for a particle size of 39 nm. Second, the sensing volume of the immobilized gold nanoparticles, defined as the distance from the surface within which a bulk refractive index change will result in a change in the optical signal, increases with particle size and peaks for 39 nm diameter nanoparticles. Based on these results, an optimized sensor was fabricated using 39 nm gold nanoparticles, and its detection limit for biotin-streptavidin binding was found to be ~1 nM. NanoSPR on a chip is attractive for biosensing because of simple solution based assembly and ability to measure extinction spectrum using widely available UV-vis spectrophotometers.

10:20am **NS+BI-FrM7 Ultrasensitive Nanowire Sensor for Drug Discovery and Medical Diagnostics**, ***W. Wang***, Harvard University

Semiconductor nanowires represent a novel class of nanostructured materials with a wide range of future applications from molecular electronics to biotechnology. Using appropriate fabrication procedures, our group has previously demonstrated that field-effect transistors (FETs) made from p-type Si nanowires possess electronic characteristics exceeding that of conventional planar devices. This outstanding electronic property makes nanowire FETs ideal transducers in a sensor system with label-free, real-time detection capability. Furthermore, sensors made from Si nanowires offer additional advantages over other type of sensors including the ease to differentially modify many nanowires for multiplexed sensing, the potential to be very small and inexpensive, and most importantly the unparalleled extreme sensitivity to the point where single molecule detection is possible. With successful chemical modification to covalently immobilize biological receptors onto the surface of nanowires, we showed that a nanowire FET can be configured into a nano-scale sensor and the binding of charged ligands to the receptors generates specific electrical responses in a quantitative manner. We first applied this strategy to develop a sensitive detector for prostate cancer by measuring the levels of PSA, a marker for prostate cancer. The sensor was shown to detect PSA as low as 0.025 pg/ml (7fM). In addition to medical diagnostics, the combined advantages of label-free detection and extreme sensitivity offer a unique opportunity to configure the nanowire sensors into a drug discovery platform. Using Abl kinase/ATP/Gleevec as a model pathological system (in chronic myeloid leukemia), we have demonstrated the possibility to visualize drug action, or small molecule/protein interactions in real time. Lastly, because of the high sensitivity inherent to the nanowire sensors, individual binding/unbinding events of single molecules can be resolved electrically.

10:40am **NS+BI-FrM8 Nanopores in Ultrathin MOS-compatible Membranes for Electrical Detection of DNA**, ***T. Kim***, *J. Heng, V. Dimitrov, C. Ho,* University of Illinois at Urbana-Champaign; *A. Kornblit, F. Klemens, J. Miner, W. Mansfield, C. Pai, T. Sorsch,* New Jersey Nanotechnology Consortium; *G. Timp,* University of Illinois at Urbana-Champaign

We are developing a revolutionary type of silicon integrated circuit that incorporates MOS technology with an on-chip nano-pore mechanism for directly sensing the electrical activity of bio-molecules such as ions, proteins or DNA. The electronic detection of biological analytes could have several advantages over the conventional scheme, fluorescent microscopy, which is used so prevalently in biology to discriminate the experimental outcomes. For example, if each analyte has a characteristic signature, then an electronic biosensor could facilitate the analysis of the data by eliminating the need for sensitive dyes, thereby improving the dynamic range for detection. We have recently discovered a method to produce ~1-2nm diameter pores (a size comparable to the secondary structure of a protein) in membranes made from materials such as Si, SiO@sub 2@, and Si@sub 3@N@sub4@ that are compatible with MOS fabrication technology. We have adopted this method to create nano-pores spanning a high quality ~2-5nm thick SiO@sub 2@ membrane that constitutes part of the gate electrode in a Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) amplifier. Here, Hwe report on the fabrication of nanometer-scale pores in MOS compatible materials using a high voltage, tightly focused electron beam, and on time-resolved measurements of the transport of 100bp to 1500bp DNA through a range of pore diameters (2-8nm) and membrane thicknesses (2-30nm).

11:00am **NS+BI-FrM9 Electrically Switchable Nanostructured Superhydrophobic Surfaces**, ***J.A. Taylor***, New Jersey Nanotechnology Consortium; *T.M. Schneider, S. Yang,* Bell Laboratories, Lucent Technologies; *A. Kornblit,* New Jersey Nanotechnology Consortium; *T.N. Krupenkin,* Bell Laboratories, Lucent Technologies

Dynamically switchable nanostructured surfaces are investigated. Behavior of liquids on these surfaces is studied both experimentally and theoretically. Three major states of a liquid drop on these surfaces are demonstrated. The states include highly mobile rolling ball, immobile droplet, and complete wetting state. The transitions between these states were dynamically induced by applying a voltage between a liquid and a nanostructured substrate. Droplet contact angle was measured as a function of applied voltage and nanostructured layer geometry. The obtained results show quadratic dependence of the cosine of the contact angle on voltage, which is in good agreement with the typical electrowetting behavior. The details of interaction of liquids with the nanostructured layer were investigated using SEM technique. The proposed approach potentially allows novel methods of manipulating microscopically small volumes of liquids. This includes essentially frictionless liquid transport, the ability to selectively immobilize the droplets at any given time or position, as well as dynamic control over the penetration on liquids through the nanostructured layer. The obtained results potentially open new and exciting opportunities in microfluidics, chemical microreactors, bio/chemical detection, thermal management of microelectronics, bio-optics, and many other areas.

11:20am **NS+BI-FrM10 Engineering Information Processing in Biological Systems**, ***R.H. Blick***, University of Wisconsin-Madison **INVITED**

The key aspect of this work is to present methods for understanding and engineeringinformation processing in nanoscale biological systems. The

systems we are focusing on are nanometer-sized ion channels integrated in high frequency circuits. The ion channels are embedded in bilipid membranes, which are brought to microstructured glass chips for direct transport measurements. Recording the passage of ions is successfully performed and first results on high-frequency response are shown.

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