DNA Topical Conference
Room 311 - Session DN+BI-MoM
DNA Structures and Surfaces
Moderator: D.G. Castner, University of Washington

8:20am **DN+BI-MoM1 Design Rules for the Assembly of DNA Modified Nanoparticles: Influence of Surface Chemistry, Ionic Strength, and a Polycation*, K.J. Jeong*, *S. Bhattacharya, D.B. Janes, G.U. Lee,* Purdue University

DNA-modified gold nanoparticles are promising materials for the efficient assembly of hierarchical nanostructures because of their ability to self-assemble specifically. In this study, the affect of the DNA surface immobilization chemistry, ionic strength of the solution, and a polycation on the efficiency of assembly of DNA-modified gold nanoparticles on DNA-modified gold surfaces was quantitatively studied. The hybridization efficiency was studied for DNA gold nanoparticles on DNA surfaces treating with 6-mercapto-1-hexanol (MCH) and it was found to significantly enhance the density of nanoparticles found on the surface. Ionic strength played a complex role on the observed assembly of the particles. In pure water, no assembly was possible because the diffusion of the nanoparticles was prevented by strong electrostatic repulsion. In ionic strengths greater than 0.1M NaCl, electrostatic repulsion was effective only at short ranges so that the nanoparticles can assemble through DNA hybridization. However, at ionic concentrations greater than 0.4M NaCl, a slight decrease in assembly was observed, which is attributed to the partial loss of particles in solution through aggregation. Theoretical analysis of these results based on the surface forces that govern the interactions between DNA-modified gold surfaces - electrostatic, van der Waals, and steric forces - confirms the interpretation above. One important conclusion drawn from the theoretical analysis is that the forces that govern the stability of DNA-gold colloids are not DLVO forces but a mixture of electrostatic and steric interactions. Spermidine, a polycation, was used to irreversibly lock-in the nanoparticles assembled on the surface so that the samples could be rinsed with water and dried. The results found in this article provide new insight into design rules for controlling the efficient assembly of DNA-modified nanoparticles.

8:40am **DN+BI-MoM2 DNA and Protein Microarray Printing on Silicon Nitride Waveguide Surfaces*, P. Wu,*** Colorado State University, US*; P. Hogrebe,* MSU*; D.W. Grainger,* Colorado State University

All bioanalytical assays using surface-capture of target analytes suffer from non-ideal sensitivity and selectivity. We have recently focused on microarray formats on optical waveguide surfaces to improve assay performance. Sputtered silicon nitride optical waveguide surfaces were silanized and modified with a hetero-bifunctional crosslinker to facilitate thiol-reactive immobilization of contact-printed DNA probe oligonucleotides, streptavidin and murine anti-human interleukin-1b capture agents in microarray formats. X-ray photoelectron spectroscopy (XPS) was used to characterize each reaction sequence on the native silicon oxynitride surface. Thiol-terminated DNA probe oligonucleotides exhibited substantially higher surface printing immobilization and target hybridization efficiencies than non-thiolated DNA probe oligonucleotides: strong fluorescence signals from target DNA hybridization supported successful DNA oligonucleotide probe microarray fabrication and specific capture bioactivity. Analogously printed arrays of thiolated streptavidin and non-thiolated streptavidin did not exhibit noticeable differences in either surface immobilization or analyte capture assay signals. Non-thiolated anti-human interleukin-1@beta@ printed on modified silicon nitride surfaces reactive to thiol chemistry exhibited comparable performance for capturing human interleukin-1@beta@ analyte to commercial amine-reactive microarraying polymer surfaces in sandwich immunoassays, indicating substantial non-specific antibody-surface capture responsible for analyte capture signal.

9:00am **DN+BI-MoM3 DNA: Not Merely the Secret of Life*, N.C. Seeman,*** New York University **INVITED**

Structural DNA nanotechnology uses the concept of reciprocal exchange between DNA double helices to produce branched DNA motifs, like Holliday junctions, or related structures, such as double crossover (DX), triple crossover (TX), paranemic crossover (PX) and DNA parallelogram motifs. We have worked since the early 1980's to combine DNA motifs, using sticky-ended cohesion, to produce specific structures. From branched junctions, we have constructed DNA stick-polyhedra, whose edges are double helices, and whose vertices are the branch points of DNA branched junctions. These include a cube, a truncated octahedron, and an irregular graph. We have also made topological targets, such as deliberately designed knots and Borromean rings. Recently, we have begun to template the topology of industrial polymers, such as nylon, with DNA-like scaffolds. Nanorobotics are key to the success of nanotechnology. We have used two DX molecules to construct a DNA nanomechanical device by linking them with a segment that can be switched between left-handed Z-DNA with right-handed B-DNA. PX DNA has been used to produce a robust sequence-dependent device that changes states by varied hybridization topology. The sequence-dependent nature of this device means that a variety of them attached to a motif can all be addressed individually. Recently, we have used this device to make a translational machine. A central goal of DNA nanotechnology is the self-assembly of periodic matter. We have constructed micron-sized 2-dimensional DNA arrays from DX, TX and two kinds of parallelogram motifs. We can produce specific designed patterns visible in the AFM from DX and TX molecules. We can change the patterns by changing the components, and by modification after assembly. In addition, we have generated 2D arrays from DNA parallelograms. These arrays contain cavities whose sizes can be tuned by design. Recently, we have used robust triangular motifs to produce honeycomb-shaped arrays.

9:40am **DN+BI-MoM5 Adsorption of DNA-wrapped Carbon Nanotubes on SAM Modified Gold Surfaces*, R.A. Zangmeister***, *A.M. Opdahl, M.J. Tarlov,* NIST

We are studying the structure of DNA-wrapped carbon nanotubes (CNTs) on gold surfaces modified with alkanethiol self-assembled monolayers (SAMs). Our goal is to understand how DNA-wrapped CNTs interact with surfaces of varying chemical functionality and to use this knowledge to develop general strategies for controlling the assembly and alignment of DNA-wrapped CNTs on surfaces. Recently, Zheng and coworkers found that single-stranded DNA wraps around CNTs, improving their solubility in aqueous solutions and enabling their separation according to diameter and electronic properties.@footnote 1@ We postulate that the well-defined nature of the DNA-conjugated CNTs will allow their precise assembly and alignment on surfaces. We have examined the adsorption of DNA-wrapped CNTs on hydrophobic, hydrophilic, charged, and spatially patterned alkanethiol SAMs on gold. These samples are characterized using reflection absorption FTIR, scanning electron microscopy, and scanning probe microscopy. We have found that DNA-wrapped CNTs preferentially adsorb to positively charged amine terminated SAMs and to bare gold surfaces versus hydrophobic methyl terminated or negatively charged carboxylic acid terminated SAMs, indicating that electrostatic interactions play a major role in the deposition of these materials. In addition, general strategies for controlling the density and alignment of DNA-wrapped CNTs using alkanethiol SAMs will be discussed. @FootnoteText@ @footnote 1@Zheng, M., et al. Nature Materials 2003, 2, 338-342.

10:00am **DN+BI-MoM6 Surface Characterization of DNA Immobilization on Silane-modified SiO@sub x@*, G.M. Harbers,*** Colorado State University*; L.J. Gamble, D.G. Castner,* University of Washington*; D.W. Grainger,* Colorado State University

Fundamental studies must better understand and characterize DNA-immobilized surfaces to improve DNA microarray assay performance. DNA probe immobilization and target capture in microarray formats are quantified with standard fluorescence and radiometric assays. However, stable, efficient bulk immobilization methods that faithfully replicate microarray formats, but also permit high-sensitivity surface analysis with XPS and NEXAFS, are desired. While thiol-immobilized DNA probes on gold remain popular, silane coupling layers on oxides are more practical by closely duplicating commercial polymer microarray slides. Yet, silane coupling remains problematic, and common amine-terminated silane chemistry requires heterobifunctional crosslinking to immobilize thiol- or amine-modified oligo-DNA. Both commercial microarray substrates and silanated surfaces contain C, O, and N, confounding DNA surface analysis. Although phosphorus (at ~ 5%) is unique to DNA, at low DNA densities, P is difficult to detect and its XPS binding energies overlap with silicon plasmon peaks, making analysis confusing. Therefore, we compare silane coupling agents and substrates lacking nitrogen to follow unique DNA nitrogen and when possible phosphorus signals. Several amine- and thiol-reactive silanes on silicon oxide substrates were monitored with XPS at each surface coupling stage. In addition to a qualitative assessment of DNA density using XPS with expected N/P ratios of ~3.8, immobilized oligo-DNA densities and hybridization efficiencies were quantified using @super 32@P-DNA radiolabeling. DNA densities scaled with oligo-DNA feed concentrations (5nM-2µM) and target hybridization depended on oligo-DNA densities,

ranging from ~100% at low densities (~10@super 11@ molecules/cm@super 2@) to <10% at high densities (~10@super 13@ molecules/cm@super 2@). NEXAFS, used to determine oligo-DNA probe and target duplex orientation, demonstrated little to no DNA surface orientation under these conditions.

10:20am **DN+BI-MoM7 From Fundamental Properties to Applications of DNA Monolayers*, R. Levicky,*** Columbia University **INVITED**

We investigate self-assembled DNA monolayers on metal and dielectric supports. Chains ranging in size from oligonucleotides to gene-sized polymers have been site-specifically attached without detectable side reactions in an end-tethered, "polymer brush" geometry. On metal supports, polythiol-mediated anchoring can be used to provide highly permanent immobilization of the nucleic acid. X-ray photoelectron spectroscopy (XPS), dynamic light scattering, and electrochemical methods have been applied to investigate the charging behavior, counterion partitioning, and organization of DNA monolayers on metal supports, and to evaluate label-free electrochemical approaches for monitoring interfacial hybridization reactions. The interfacial capacitance of end-tethered DNA films has been interpreted within a polyelectrolyte brush model. The observed trends with ionic strength and strand surface coverage generally agree with physical expectations, although as yet not understood increase in capacitance with decrease in ionic strength is observed for densest monolayers. Diagnostic applications are being pursued through development of near-field imaging methods and of active microelectronic substrates that integrate signal detection and processing functionality "on-chip." Near-field measurements offer a label-free technique with a sensitivity comparable to that of fluorescence-based systems currently in widespread use. Microelectronic biochips replace costly macroscopic instrumentation by integration of equivalent function within the solid support, using affordable CMOS microfabrication. Results from validation studies of these emerging technologies and their promise for more portable, simplified, and economical assays will be also described.

11:00am **DN+BI-MoM9 Electric Field Assisted Assembly of 2D and 3D DNA Nanostructures*, M.J. Heller,*** University of California, San Diego **INVITED**

Active microelectronic arrays which have been developed for genomic research and DNA diagnostic applications may also have potential for nanofabrication applications. These microarray devices are able to create reconfigurable electric field transport geometries on their surface which allows charged reagent and analyte molecules (DNA, RNA, oligonucleotide probes, amplicons antibodies, proteins, enzymes, nanoparticles and micron sized semiconductor devices) to be moved to or from any of the microscopic test sites on the device surface. These microelectronic array devices have the potential for many nanofabrication applications, including the directed self-assembly of molecular, nanoscale and microscale components into more complex 2D and 3D nanostructures and for creating higher-order mechanisms. This type of electric field assisted self-assembly using active microelectronic arrays is also being investigated as a method to carry out the selective functionalization of nanocomponents with high precision.

11:40am **DN+BI-MoM11 New Approach in Electrochemical DNA Hybridization Detection with Adjacent Impedance Probing*, K.S. Ma,*** *H. Zhou, J. Zoval, M. Madou,* University of California, Irvine

Over the past two decades, the rapidly progressing development of electrochemical DNA biosensors have attracted substantial research efforts. Within the large number of electrochemical detection approaches, self-assembled monolayers (SAM) have been shown to be a convenient technique for immobilization of oligonucleotides probes on the gold electrodes. With this type of surface preparation, thiol-labeled ssDNA spontaneously adsorbs onto the gold surface, however, both via thiol-gold linkage (specific) and via non-specific interactions, thus introducing undesirable random orientations of the ssDNA molecules. These random orientations are undesirable because of the resulting non-perfectly-polarized membrane on the electrode. To avoid the problems caused by non-specific adsorption of probes on electrode surface, many methods have been studied intensively. Paleek et al. worked on a new assay method called the "two-surface strategy". In our current study, a unique method was employed for DNA hybridization detection. Using micro-fabrication processes, the two-surface concept was proved to be feasible in the same spatial domain. In this case, the DNA hybridization microspot is made for the bio-recognition event and a bare adjacent conductor electrode is designed for generating the impedance change through insulator deposition. The Electrochemical Impedance Spectroscopy was employed for the measurements. At medium frequency, a noticeable increase of impedance modulus appeared in the Bode plot. For non-complementary measurement, there was no change of impedance modulus. By this biosensor, upon DNA hybridization and subsequent deposition of the enzymatic reaction product, we had found significant improvement on the signal of DNA hybridization detection. Further studies such as lowest detection limitation are required before any practical applications.

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