MEMS and NEMS
Room 207 - Session MN-MoA

Materials and Processes for Bio-MEMS and Bio-NEMS

Moderator: C.A. Zorman, Case Western Reserve University

2:00pm **MN-MoA1 Detection of Specifically Bound Biological Mass with Resonant Nanobeams and Nanochannels**, ***S.S. Verbridge***, *J.M. Moran-Mirabal,* Cornell University*; D.M. Tanenbaum,* Pomona College*; H.G. Craighead,* Cornell University

Nonlithographic techniques have been used for the fabrication of two types of nanostructures, used for detection of biological molecules. Polymeric electrospun fibers with dimensions on the order of 100 nm have been used in combination with photolithography to define free standing beams and channels, made of silicon nitride and glass, respectively. Beams are made by using electrospun fibers as etch masks, and channels by using fibers as a sacrificial core. Critical dimensions of both types of structure are hence determined by polymer nanofiber sizes. Nitride beams with resonant frequencies above 10 MHz, and quality factors above 10,000 have been used as binding sites for biological molecules. Nonspecific binding of proteins such as streptavidin to entire beams, as well as targeted binding using specific thiol linkages on gold binding sites (also defined with photolithography), have both been explored. These free standing nanobeams have been operated in resonance for the detection of the bound biological mass. Suspended glass channels have been used to observe fluorescence from labeled cellulase enzymes, at the single molecule level. Directions for using suspended nanochannels to do mechanical mass detection are also being explored, to make this sort of resonant nanostructure based mass detection technique more compatible with natural fluid systems of biological interest.

2:20pm **MN-MoA2 Optically Driven Nanomechanical Resonant Structures for Detection of Single Molecules**, ***B. Ilic***, *Y. Yang, K. Aubin, R. Reichenbach, J. Huang,* Cornell University*; S. Krylov,* Tel Aviv University, Israel*; H.G. Craighead,* Cornell University

Resonant nanoelectromechanical systems (NEMS) are being actively investigated as sensitive mass detectors for applications such as chemical and biological sensing. NEMS devices, made by lithographic techniques, can be formed in highly uniform arrays in a form that can be readily integrated with motion transduction and microfluidic systems. The types of materials that can be structured in this way have low mechanical losses providing a high mechanical quality factor of the oscillators and therefore well defined resonant frequencies. The very specific resonant frequencies and small mass of the oscillator allows for detection of small amounts of additional bound mass. Experimental investigations illustrate that the ability to engineer nanoscale features on the surface of NEMS devices, combined with localized chemical functionalization, allows for specificity and calibration of these devices as detectors. In our work, we have detected the binding of functionalized 1578 base pair long double-stranded disulfide modified double stranded DNA molecules to nanomechanical oscillators by measuring the resonant frequency shift due the added mass of the bound molecules. The resonant frequency of individual oscillators in an array of resonator devices was measured by thermo-optically driving the individual devices and detecting their motion by optical interference. Localized binding sites created with gold nanodots create a calibrated response with sufficient sensitivity and accuracy to count small numbers of bound molecules. The number of bound molecules on each device was quantified as proportional to the measured frequency shift with a proportionality constant determined experimentally and verified by modeling of the mechanical response of the system. For the smallest and most sensitive cantilevers the mass sensitivity was 194Hz/attogram.

2:40pm **MN-MoA3 Biofabrication: Enlisting Biological Materials for Fabrication**, ***G.F. Payne***, *L.Q. Wu, H. Yi, W.E. Bentley, J.N. Culver,* University of Maryland Biotechnology Institute*; G.W. Rubloff, R. Ghodssi,* University of Maryland **INVITED**

Biological materials offer unique properties that facilitate fabrication. Well-known are the self-assembly properties of biological materials that enable the bottom-up self-fabrication of nano-scale structures (e.g. nanowires and nanotubes). Yet, biological materials offer additional properties. They can be acted upon by enzymes enabling highly selective biocatalysts to be enlisted for enzymatic-assembly. And, biological materials often possess stimuli-responsive properties that enable a range of external stimuli to be enlisted for directed-assembly. We are studying the stimuli-responsive amino-polysaccharide chitosan as a versatile interface material. Chitosan's pH-responsive electrostatic properties allow its directed assembly (i.e. electrodeposition) in response to localized electrical signals that can be imposed from electrodes. Chitosan's directed-assembly can be controlled by controlling deposition conditions, and high lateral resolutions have been observed when the electrical signals are imposed from micropatterned electrodes. Once neutralized, the chitosan deposit is stable (chitosan is insoluble under neutral and basic conditions) although it can be re-solubilized by washing with mild acid. In addition to its stimuli-responsive properties, chitosan also offers chemical properties that permit the facile conjugation of proteins and nucleic acids to previously-deposited chitosan. These chitosan-bound proteins and nucleic acids can confer important functional properties (e.g. recognition, catalysis and binding). We are particularly interested in using the hybridization capabilities of chitosan-bound nucleic acids to serve as "nucleation sites" for the self-assembly of higher-ordered structures. Together, the results demonstrate that chitosanâ?Ts unique properties enable the integration of biological materials for biofabrication at the micro- and nano-scale.

3:20pm **MN-MoA5 Toward a Chitosan-Based Micromechanical Biosensor**, ***S.T. Koev***, *M.A. Powers, H. Yi, R. Ghodssi,* University of Maryland, College Park

In this work, the electrically deposited polysaccharide chitosan is used to biofunctionalize a microcantilever biosensor which detects the presence of target molecules on the chitosan as a shift in the resonant frequency of the cantilever. We have previously demonstrated the use of chitosan for spatially selective assembly of various biomolecules and now extend its functionality to a micromechanical sensor. Chitosan offers significant advantages over other materials commonly used for immobilization of biomolecules. The electrodeposition of chitosan would allow facile patterning of different probe biomolecules in sensor arrays. Additionally, chitosan's surface roughness, which can be controlled by the deposition conditions, leads to a large effective surface area for target molecule coupling. The microcantilever consists of layers of chitosan (100 nm), Cr/Au (110 nm), and Si@sub3@N@sub4@ (500 nm) fabricated on a Si substrate. The Au layer is used both for chitosan deposition and electrostatic actuation. The cantilever's resonant frequency is measured by actuating it at different frequencies and recording the amplitude with an optical profilometer in dynamic mode. Amine terminated ssDNA probe molecules are coupled to the chitosan amine groups using glutaraldehyde as a crosslinker and are hybridized with their complements. Resonant frequency measurements are performed after each of the following steps: chitosan deposition, addition of probe DNA, and addition of complementary target DNA. The data are analyzed to extract the surface mass density of DNA immobilized on the chitosan. The detailed fabrication, characterization, and measurement results will be presented.

4:00pm **MN-MoA7 Polymeric Intermediate Layer Bonding in Micro/Nano Devices at Low Temperature for Bio-MEMS/NEMS Applications**, ***M. Dhayal***, Dongshin University, South Korea

In this study using low pressure plasma polymerized thin intermediate layer bonding process the silicon-to-silicon and glass-to-glass substrate bonding in micro/nano devices was successfully carried out. This process has advantage for bonding of glass and silicon types of substrate materials al low bonding temperature up to 130oC. The bond strength was more than 2 MPa for an about 100 nm intermediate plasma polymerised acrylic acid, p-xylenne, styrene, 1-vinyl-2-pyrrolininne and allylamine intermediate layers on glass and silicon substrates. The intermediate plasma polymerised thin layer bonding strange was also tested for continuously more than 24 hours with changing the room temperature from 25 to 35 oC and bonding does not shows any problem. This bonding process has advantage in the micro/nano devices applications in biology where the control of surface properties is required and also this process allows the device to be reusable. In this study the fabrication of bio-MEMS was carried out using plasma polymerisation process with optical lithography, wet and dry etching techniques on silicon/glass substrate. An asymmetric electrode array used for micro pump in micro fluidic device with small electrode (4 Âµm wide) separated from the large electrode (20 Âµm wide) by 20 Âµm and 6 Âµm gaps in both sides respectively.

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