Tuesday Afternoon Poster Sessions

BioMEMS Topical Conference
Room: Hall D - Session BM-TuP

BioMEMS

BM-TuP1 Electrowetting Using Probe of Atomic Force Microscope as Mobile Electrode, ***X. Ling***, *B. Bhushan*, The Ohio State University

The wetting behavior of liquid droplet on nanostructured surface can be dynamically tuned using electrowetting technique. A conductive AFM probe is used as a mobile electrode to replace the normally fixed electrode in conventional electrowetting setup. The forces involved in the electrowetting process are quantitatively measured from the deflection of AFM cantilever. The AFM tip geometry is precisely determined using SEM and calibration standard. The force between the AFM tip and the droplet is modeled and quantitatively compared with experimental results. By actuating the AFM probe vertically and laterally using the integrated piezo-driver, the droplet is actuated on the nanostructured surface in a fully controllable way due to the capillary force between the AFM tip and the droplet. The actuated droplet is used as a nano-vehicle to effectively transport and/or arrange other nano-objects on surface with capillary-induced manipulation, which opens a new way to integrate nanometer-sized building-blocks that were not movable with other methods.

BM-TuP2 Nanoscale Adhesion, Friction and Wear Studies of Biomolecules on SAM-Coated Silicon Based Surfaces, *B. Bhushan, **K.J. Kwak**, S. Gupta, S. Lee*, The Ohio State University

Protein layers are deployed over the surfaces of microdevices such as bioMEMS and bioimplants as functional layers that confer specific molecular recognition or binding properties or to facilitate biocompatibility with biological tissue. When a microdevice comes in contact with any exterior environment, like tissues and/or fluids with a variable pH, the biomolecules on its surface may get abraded. Silicon based bioMEMS are an important class of devices. Adhesion, friction and wear properties of biomolecules (e.g., proteins) on SAM coated silicon based surfaces are therefore important. These studies have been carried out on protein biomolecules using tapping mode AFM. Based on this study, adhesion, friction and wear mechanisms of biomolecules on SAM-coated silicon based surfaces are discussed.

BM-TuP3 Measurement of the Slip Length of Water Flow on Hydrophilic, Hydrophobic and Superhydrophobic Surfaces, *Y. Wang, **B. Bhushan***, The Ohio State University

The growing interest of boundary slip at liquid-solid interface in micro/nano scale is an important issue in microfluidics systems, where lower liquid flow friction is generally desirable. Recent studies have shown that the no-slip boundary condition is not always valid on micro/nano scale, especially on hydrophobic. Theoretical and experimental studies suggest that at the liquid-solid interface, the presence of gas bubbles is responsible for the breakdown of the no-slip condition for hydrophobic surfaces. The degree of boundary slip at liquid-solid interfaces is usually quantified by a parameter called slip length, which infers a distance between a liquid-solid interface and a virtual no-slip interface. Atomic force microscopy is a powerful tool to measure slip length. It has also been used to image nanobubbles in tapping mode. Although the slip length has been reported on both hydrophilic and hydrophobic surfaces, the direct experiment evidence has not been given between nanobubble and apparent slip on hydrophobic surfaces, as well as the relationship between bubbles' properties and slip length. In this study, the colloidal probe techniques is used to measure hydrodynamic force on hydrophilic, hydrophobic and superhydrophobic surfaces with AFM. The slip length is obtained based on a model proposed in the literature. By combining nanobubble images on hydrophobic and superphdrophobic surfaces, the contribution of nanobubbles to boundary slip is studied with known bubble properties, such as size and distribution density. A model is presented for nanobubbles' friction reducing mechanisms.

BM-TuP4 Electrical Assay for Real-Time Monitoring Cardiomyocyte Apoptosis, ***Y. Qiu***, *X. Zhang*, Boston University

Deregulated cardiomyocyte apoptosis is a critical risk factor in a variety of cardiovascular diseases. Though enzymatic DNA fragmentation is most commonly used criteria of apoptosis at the level of individual cardiomyocytes, the capability of detecting cell detachment will provide instant information at early phase of apoptosis. Furthermore, the assays used to detect DNA fragmentation are all invasive to living cells, which disables real-time monitoring of the whole process. In this work, we developed an impedance-sensing assay for real time monitoring cardiomyocyte apoptosis induced by tumor necrosis factor alpha (TNF-alpha) based on recording the change in cardiomyocyte adhesion to extracellular matrix (ECM). Electrochemical impedance spectroscopy (EIS) was employed in impedance to process the impedance spectra, followed by manual calibration with electrical cell-substrate impedance sensing (ECIS) technique. Adhesion profile of cardiomyocytes undergoing cell death process was recorded in a time course of equivalent cell-substrate distance. Multiple concentration levels of TNF-alpha (from 10 to 80 ng/mL) were applied to the cultured cardiomyocytes and the concentration-related adhesion profiles were recorded for the cell death process. An optimal concentration of TNF-alpha (20 ng/mL) was determined to induce cardiomyocyte apoptosis rather than necrosis because of its mild slope of developing cell detachment in 24-hour real-time monitoring. It was also observed in the Trypan blue exclusion (TBE) results that a gradual and significant increment in cell death rate was achieved with a concentration level of 20 ng/mL. Treat with optimal concentration of TNF-alpha, the cardiomyocytes first experienced a transient drop in cell-substrate distance followed a sustained cell detachment. The equivalent cell-substrate distance increased from 59.1 to 89.2 nm within 24 hours. The early change of cell adhesion was proven related to cardiomyocyte apoptosis with the following TUNEL test in which the treated cardiomyocytes suffered an apoptotic percentage of 21.1 ± 5.5 % (vs. 5.9 ± 2.5 % in the control sample). This novel assay has the potential to become a valuable high-throughput experimental approach in studying in vitro cardiomyocyte apoptosis research.

BM-TuP5 Parylene Electrothermal Valves for Rapid In Vivo Drug Delivery, ***P.-Y. Li***, *D.P. Holschneider, J.-M.I. Maarek, E. Meng*, University of Southern California

Two single-use electrothermal valves featuring low power (mW) and rapid operation (ms) were designed, modeled, fabricated, and tested. They share a common layout consisting of a composite membrane (Parylene/Pt/Parylene) situated in the flow path between two catheter segments. Current applied to the Pt thermal element initiates Joule heating that leads to thermal degradation or melting of the membrane and causes the valve to open. Compared to previous work employing metal membranes, Parylene enables low power operation (thermally degraded (125-200°C) or melted (290°C) at much lower temperatures). Parylene also enables large robust membranes for larger effective valve opening area (in this case, 330-500 μm). Membrane designs were mechanically modeled to assess performance using a large deflection (Parylene only) and nonlinear FEM models (composite). The nonlinear model indicates 1.53GPa maximum stress of the Pt element under 1 atm pressure (peak under normal operation) which is less than its tensile strength (1.83GPa); modeling and load deflection experiments showed good agreement. Transient thermal FEM modeling and video microscopy were used to investigate thermal events leading to valve opening; simulation and experimental results were in close agreement. The temperature coefficient of resistivity of the Pt element and the resistance change as a function of applied current were obtained. These results allowed prediction of the temperature of the Pt thermal element and determination of the appropriate operating current. For the prototype valve having a serpentine Pt element spanning the valve area, 25-50 mW was required to open the valve under constant current operation in air and a current ramping rate of 0.1 mA/sec was the optimal condition for valve opening for use with water. The best opening time achieved with this design was 100 ms in air but several seconds in water. The optimized valve further improves the opening speed; the Pt element (straight and serpentine) was defined only at the perimeter of the valve except for a small gap where the element connects to contact pads. Preliminary results indicate that the optimized valve can be opened in water in the millisecond range (100 mW). We also demonstrate successful application of our valve in a wirelessly operated minipump that allows bolus drug infusion in animals.

BM-TuP6 Mapping Smooth Muscle Cell Contractile State Regulated by Contractile Proteins using a Novel BioMEMS Moire Mapping Sensor, ***X.Y. Zheng***, *X. Zhang*, Boston University

Abnormal vascular smooth muscle cell contractility plays an important role in the pathogenesis of hypertension, blood vessel spasm, and atherosclerosis. This paper presents the mapping of smooth muscle cell contractility using a novel optical moiré method. We utilized coherent laser beams to illuminate periodic polymeric substrates where isolated cells were cultured. The diffraction phenomena of coherent laser beams through the polymeric periodic substrates where living cells were cultured introduces moiré patterns and can be used to real-time mapping the cell-substrate traction forces. The PDMS micropillar arrays were embedded between large sidewalls for cell guidance. A polycarbonate flow perfusion chamber is

sealed under the chip. The same chip with imbedded pillars with aspect ratio of 1:3 was mounted on a rotational stage parallel to the first substrate. Diffraction moiré patterns can be generated by illuminating coherent beam via two parallel grating lines or grids. The grating lines served as reference gratings for diffraction moiré pattern generation in (0,1,0) or (1,0,0) direction whereas two-dimensional moiré fringes can be formed via two paralleled imbedded pillars. Therefore, contraction of the vascular smooth muscle cells can be real time "magnified" and "mapped" through moiré pattern evolutions. For contractility mapping of vascular smooth muscle cells, we considered the cell total area, cell length and width. On the other hand, we measured the distortion area of the moiré patterns, moiré pattern length and width. In the experiment, these two factors were shown to be consistent. Further, vascular smooth muscle cells were cultured on substrates with serum media to develop focal adhesion, and then the cells were relaxed on serum free media for another 48 hours followed by treating SMCs with contractile agonist lysophosphatidic Acid. We found that the area of the distorted moiré patterns produced on two overlapped periodic substrates were inversely correlated with the distortion of the moiré patterns, thereby indicating that the contraction of vascular smooth muscle cells were inversely correlated with the initial spreading developed in serum. We anticipate that this method will increasingly provide more applications and cell biological insights in vascular cell contraction mechanism study.

BM-TuP7 Toward a Selective Optical Biosensor for Integrated Biofilm Detection, ***M.T. Meyer***, *S.T. Koev, R. Fernandes, W.E. Bentley, R. Ghodssi*, University of Maryland

Certain types of bacteria regulate gene expression through quorum-sensing, the detection of extracellular levels of bacterial signaling compounds. Once bacteria sense their population is sufficiently large to overwhelm a host's immune system, they will aggregate and form a pathogenic matrix of bacteria, or biofilm. While this phenomenon is not fully understood, it is of interest to study biofilms to gain knowledge toward developing new antibacterial treatments. We have developed a platform for examining bacterial biofilm growth and response in a microfluidic environment using optical monitoring of selectively deposited Escherichia coli. Bacterial growth over time was quantified via optical absorbance using an external photodiode; the use of an optical sensor isolated from the fluidic environment allows for more reliable sensor operation as well as increased sensitivity. Two bacterial adhesion layers were investigated, including the amino-polysaccharide chitosan and a fusion protein (E72G3), consisting of a hydrophobic domain and an antibody-binding protein G domain, bound to antibodies against E. coli. E. coli cells were immobilized on electrodeposited chitosan, and biofilms were grown over a period of 48 hours. While chitosan can be selectively deposited and promotes bacterial adhesion, results show that material irregularities impede optical observation of the progression of biofilm growth. E72G3 was also used to immobilize E. coli by depositing the proteins on a patterned hydrophobic surface, then immobilizing antibodies against E. coli on E72G3. This method of bacterial deposition can be extended to numerous other pathogens by virtue of the fusion protein's antibody-binding properties. Optically detectable biofilm formation was confirmed on this spatially and biologically selective surface. The platform can be used to quantify normal biofilm formation in addition to biofilm formation in response to external stimuli. Detailed device fabrication and testing parameters as well as experimental results will be presented. Our goal is to develop this platform into a fully integrated, compact device with highly parallel throughput for applications in discovering new antibacterial agents.

BM-TuP8 In-vitro Comparison of Activated and Sputtered Iridium Oxide Neural Microelectrodes, ***S. Negi***, *R. Bhandari, L. Rieth, R.A. Normann, F. Solzbacher*, University of Utah

To provide low impedance electrical connection between the neural electrode and the nerve, the electrodes are coated with conductive material like Iridium oxide (IrO_x) due to its higher charge injection capacity and resistance to corrosion.[1] In this report, IrO_x is deposited by two methods; activation of iridium to form activated iridium oxide film (AIROF), and reactive sputtering to form sputtered iridium oxide film (SIROF) on similar shape and size neural electrodes. The AIROF and SIROF properties are studied and the results are compared. Utah Electrode Arrays (UEAs), were used for this study.[2] To fabricate AIROF coated UEA, 99.8 % pure Ir was DC sputter deposited on to the UEA tips using an Ar pressure of 20 mTorr, and 5W power for 12 minutes to achieve 1000 Å thickness. The Ir electrodes were activated by cyclic voltammetry (CV), sweeping between -0.8 to +0.8 V versus Ag/AgCl in phosphate buffered saline (PBS) solution at the rate of 1 Hz. The SIROF films were deposited on the UEA tips by pulsed-DC reactive sputtering with 50%:50% ratio of Ar and O_2 in the ambient, keeping the chamber pressure at 10 mTorr. Ar and O_2 flow rates were both 100 sccm. The pulse frequency was at 100 kHz, the duty-cycle was 30 percent, and a power of 100 W was used to achieve thickness of 1000 Å after 20 minutes of deposition. Charge storage capacity for AIROF and SIROF coated UEAs was found to be 10 and 38 mC/cm^2, respectively. The electrochemical impedance at 1 kHz was measured for AIROF and SIROF as a function of the exposed UEA tip. At 100 µm tip exposure, AIROF and SIROF impedance were 36 and 6 kΩ respectively, while, at 20 µm tip exposure the AIROF and SIROF impedance were 200 and 50 kΩ respectively. The results indicate that decreasing the tip exposures increases impedance exponentially. SIROF coated electrodes have lower impedance and, potentially, will offer higher neural selectivity without compromising on the electrode sensitivity. The higher charge storage capacity and lower impedance makes SIROF a promising material for stimulating and recording neural signals.

[1] W. F. Agnew and D. B. McCreery (Eds), Neural Prostheses: Fundamental Studies, Prentice Hall Biophysics and Bioengineering series.

[2] K. E. Jones, P. K. Campbell, and R. A. Normann, A glass/silicon composite intracortical electrode array, Ann. Biomed. Eng., vol. 20, no., pp 423-37, 1992.

BM-TuP9 Capillary Electrophoresis Electrochemical Detector using Capacitometric Method for Endocrine Disruptor Detection, ***J.W. Yoo***, *K. Ha, Y.S. Kim, C.J. Kang, Y.J. Choi*, Myongji University, Korea

Interests in the use of polymeric materials such as polydimethylsiloxane (PDMS) and polymethylmethacrylate (PMMA) have increased over the past few years. PDMS has been widely discussed due to fine optical transparency for detection, curability at low temperatures, easily replicable molding and fine adhesion. In past, PDMS substrate based capillary electrophoresis-electrochemical detection (CE-ECD) microchips have been developed for separation and detection of endocrine disruptors. We also developed systems and measured bisphenol-A (BPA) and butylphenol as well as dopamine and catechol with various electrode structures such as ITO, Au as well as Prussian blue modified ITO and Au. Whereas, because of the sensitivity and structural dependence of measurement, capacitance based detection of these chemicals have not been attempted much so far. The strong point of the capacitometric method is that the electrode doesn't need to be contacted with a sample or electrolyte, resulting in reproducible and more reliable results than those from the amperometric detection. Thus, as long as high sensitivity of capacitance can be achieved with a suitable detection system, we can apply it to even a flowing channel system. To do that, we used a high frequency cavity resonator and measured dC/dV with a resolution of better than 10-18 F/V. A device including microchannels built using PDMS mold was also fabricated on glass substrate. In this work, we studied capacitometric detection of BPA. The separation of BPA was carried out using a 7 cm long capillary. A solution containing MES of pH 6.5 was used as separation buffer. A field of 60 V/cm was applied to a channel for separation and the same field for injection for 10 seconds. With a time evolutional monitoring of dC/dV, 100 µM to 10 mM BPA could be detected.

BM-TuP11 Microcantilever Grafted with Responsive Polymer Brushes for Glucose Sensing, ***T. Chen***, Duke University, *R. Desikan, R.H. Datar, R.P. D, T.G. Thundat,* Oak Ridge National Laboratory, *S. Zauscher*, Duke University

There is considerable interest in microcantilevers grafted with stimulus-responsive polymer brushes for sensor applications in aqueous environments, as they potentially provide a much larger cantilever bending response to changes in stimuli, such as temperature, light, chemical, and pH compared with cantilevers decorated with self-assembled monolayers (SAMs). To engineer sensitivity to specific stimuli, functional monomers can be incorporated into polymer brushes via copolymerization and functional moieties can be introduced through subsequent chemical modification. As boronic acid can bind diols through reversible boronate ester formation, incorporation of boronic acid into linear copolymers such as latex and polymer gels for the detection of glucose has been shown. Herein, we show the synthesis of novel glucose-responsive poly(N-isopropylacrylamide)-co-poly(acrylic acid)-(3-aminophenylboronic acid) (pNIPAAM-co-pAA-PBA) polymer brushes, and explore their use in a prototypical example for their potential as polymer brushes-functionalized microcantilevers firstly for the detection of blood glucose at physiologically relevant concentrations. We evaluated the stimulus-response of the polymer brushes to changes in glucose concentration and solution pH by measuring concomitant brush height changes. Glucose-responsive pNIPAAM-co-pAA-PBA brushes show a large, reversible swelling response in presence of free glucose at physiologically relevant concentrations. The deflection and surface-stress response of microcantilevers, functionalized with PBA-brushes, is substantially larger and faster than that for PBA-SAM functionalized levers. This shows the promise of pNIPAAM-co-pAA-PBA brushes for microcantilever glucose sensing applications, and demonstrates, more generally, the potential of responsive polymer brushes to sense and transduce changes in a solution environment efficiently.

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