Tuesday Afternoon, October 20, 2015

MEMS and NEMS
Room: 211A - Session MN+BI-TuA

BioMEMS/NEMS, Wearable and Implantable Devices
Moderator: Wayne Hiebert, University of Alberta and The National Institute for Nanotechnology, Beth L. Pruitt, Stanford University

2:20pm **MN+BI-TuA1 Entrepreneurial Environment for Implantable and Wearable BioMEMS**, ***Kurt Petersen***, Silicon Valley Band of Angels **INVITED**

Several converging trends are transforming the entrepreneurial process for starting MEMS companies and for transitioning MEMS devices into production and into the market. First, it is well-known that recent market set-backs have caused traditional VC funds to view any hardware start-ups with renewed scrutiny and skepticism. Hardware, and particularly bioMEMS, start-ups typically require large amounts of capital ($50-$100M) and many years (7-10), before getting close to a reasonable exit. This large investment in money and time is on top of the already inherently risky prospects for such a start-up being commercially successful. Secondly, MEMS is recognized, by investors, by foundries, and by large consumer electronics companies, as a very successful new product area because of the huge up-take of MEMS components in mobile devices during recent years. Third, key strategic issues in huge upcoming new consumer markets, such as wearables and IoT, are sensors and contextual awareness; areas which are uniquely solved by MEMS devices. And fourth, the sheer number of successful, high volume MEMS devices currently on the market, has created a huge pool of skilled MEMS developers and manufacturers which can be drawn upon for new devices and new start-up companies. All these factors dramatically influence how such companies get funding and how they operate. We will discuss all these issues as they relate specifically to new implantable and wearable MEMS start-up companies. As examples, we will also discuss a number of current technical developments/devices/companies involving implantable and wearable bioMEMS.

3:00pm **MN+BI-TuA3 MEMS Sensors Make Up the Frontline of Wireless Health Solutions: Tremendous Growth Prospects**, ***Mehran Mehregany***, Case Western Reserve University **INVITED**

Use of sensor-enabled wearable wireless health solutions to monitor the health condition of chronic disease patients is key to the quality of life of the patient and to reduction of cost of health care—by keeping the patient out of the hospital and emergency rooms. Monitoring for early intervention is key to avoiding long-term adverse outcomes for those at risk of developing chronic diseases. This presentation will elaborate on the important role that MEMS sensors play in enabling wearable, health monitoring solutions. Capturing data is the key to such solutions, which requires sensors of various modalities. MEMS sensors have the advantage s of miniaturization, integration and batch fabrication—driving size, performance and cost advantages.

Annual heath care expenditure in the United States was ~$2.7 trillion in 2011 (i.e., $8,680 per person), well above other developed countries. Health spending grew 3.9% in 2011, the same as in 2009 and 2010; spending as a share of GDP has remained stable from 2009 through 2011, at 17.9%. The US health care system is built on fee-for-service, wherein the service is reactive to illness. An aging population, longer lives and increasing cases of chronic diseases are some of the key drivers escalating health care expenditures.

Chronic diseases account for 75%+ of the US health care expenditures, i.e., $2 trillion. 141 million (45% of the population) have at least one chronic disease, 72 million of which have two or more. Top 10 significant chronic diseases are: hypertension, obesity, arthritis, asthma, chronic kidney disease, depression, chronic obstructive pulmonary disease (COPD), diabetes, sleep disorder and heart failure.

4:20pm **MN+BI-TuA7 GC-MS to GC-NOMS: A Step Towards Portable Analysis**, ***Anandram Venkatasubramanian***, *S.K. Roy, V.T.K. Sauer, W.K. Hiebert*, National Institute for Nanotechnology and University of Alberta, Canada

The Gas Chromatography (GC) – Mass Spectrometer (MS) system is the industry benchmark in research and chemical analysis. However given that MS systems are large and complicated instrumentation, chemical analyses have a long turnaround time. In this regard, portable GCs have carved a market niche but they have poor sensitivities. Recent demonstrations with Nanooptomechanical (NOMS) resonators at atmospheric pressure have proven that these kind of sensors have the breakthrough potential to improve the sensitivity of portable GCs. In this regard we have built an experimental rig to integrate the GC system with our NOMS device. The goal of this study is two-fold. One will be to replace the GC sensor with NOMS devices, integrate with the portable GCs for better sensitivity, and ultimately match the analytical power of conventional GC-MS. The other will be to demonstrate the NOMS sensing capabilities for next generation genomic applications like personalized medicine. In this regard, we have designed and developed a free space interferometry system. The probe laser is coupled in and out of the photonic waveguide using grating couplers. Using the evanescent field of the waveguide, the shift in resonant frequency of the nanoscale resonators is recorded using lock in amplifier. Here we have tracked the response of both the ring resonators using the photodetector output and the nanomechanical resonator using the phase locked loop (PLL). GC peak sensing can be done with either or both of the mechanical and the photonic sensors. During the initial testing with analyte standards we observed the ring resonator to respond faster than the nanomechanical resonator on par with the GCs flame ionization (FID) detector. We were also able to capture the analyte peaks effectively with the sensitivity of the resonators to be about 77 zg/Hz.

4:40pm **MN+BI-TuA8 Label-Free Biosensing Platform Integrating a Nanofluidic Preconcentrator with Surface Plasmon Resonance Sensors**, ***Wei-Hang Lee***, *P.S. Chung*, National Taiwan University, Taiwan, Republic of China, *P.K. Wei*, Academia Sinica, Taiwan, Republic of China, *W.C. Tian*, National Taiwan University, Taiwan, Republic of China

For bioMEMS applications, the integration of preconcentration and sensing has been studying to detect low-abundance analytes without labelling. In the past few years, an electrokinetic trapping (EKT)-based nanofluidic preconcentrator had been reported for providing a million-fold concentration factors that enable the validation of concentration process and the detection of trace and fluorescence-labelled analytes. However, the use of fluorescence-labelled analytes has suffered several disadvantages, e.g., additional sample preparation, high cost of labeling reagents, and difficulty in analyzing trace analytes. To monitor the concentration process without labelling, previously we have presented a real-time dual-loop electric current measurement system for label-free EKT-based nanofluidic preconcentrators. In this work, we further demonstrate a label-free biosensing platform by integrating a label-free nanofluidic preconcentrator with label-free SPR sensors.

The label-free biosensing platform was realized by a nanofluidic preconcentrator and two nanograting-structured SPR sensors. The preconcentrator is consisted of two parallel microchannels, i.e., one concentration channel and one buffer channel, cast in PDMS and connected by nanochannels. The two SPR sensors, i.e., one for control group and the other for experimental group, are fabricated on glass slide by e-beam lithography, e-gun evaporation and lift-off process. Then, we patterned a Nafion thin film on glass and at the position adjacent to the SPR sensors by using a microflow patterning method. Finally, the PDMS-based microchannels were sealed onto the by oxygen plasma bonding process.

We have demonstrated the ultra-sensitive label-free biosensing platform by detecting the amplified redshift magnitude of a specific range of a SPR spectrum. First, before preconcentration process, several reference spectra were measured. Second, after ten-minute preconcentration process for the 20 ng/ml BSA in PBS, a 5 nm-redshift spectrum was measured. Comparing the experimental spectrum with the reference spectra, the redshift magnitude of 20 ng/ml BSA in PBS after preconcentration process is equivalent to that of the 200 μg/ml BSA in PBS. Hence, we demonstrate a preconcentration factor of ten-thousand folds and a sensing limit of at least 20 ng/ml BSA in PBS in this label-free biosensing platform.

In summary, by utilizing the electric current measurement system and the commercial optical system, low abundance analytes can be preconcentrated and sensed by the developed biosensing platform, which enables a label-free approach on preconcentrating and detecting trace molecules with high sensitivity.

5:00pm **MN+BI-TuA9 Microparticle Patterning Using Multimode Silicon Carbide Micromechanical Resonators**, ***Hao Jia***, *H. Tang, P.X.-L. Feng*, Case Western Reserve University

In recent years, there have been increasing interests in manipulating and patterning microparticles and biological cells on microscale planar surfaces[1],[2],[3], among which "Chladni figures"[4], enabled by resonant microelectromechanical systems (MEMS)[5], offer a noninvasive, fast, and highly-controllable approach by simply programming frequency.

In this work, we report experimental demonstration of manipulating microparticles in fluidic environment using multimode silicon carbide (SiC) MEMS resonators, forming diverse microscale Chladni patterns. Silica microspheres with various diameters (0.96, 1.70, 3.62, 7.75μm) sprinkled onto suspended surfaces of SiC doubly-clamped beams (60×10μm, 100×10μm and 100×20μm) and square trampolines (50×50μm and 90×90μm) are quickly manipulated into one dimensional (1D) and two dimensional (2D) geometrical patterns, such as "dots (.)", "line (/)", "cross (×)" and "circle (○)" by piezoelectrically exciting those resonators at their flexural resonance modes.

SiC MEMS resonators, with its unique biocompatibility[6](indicating biological applications), are fabricated based on a SiC-on-Si platform, with device structures patterned by the focused ion beam (FIB) and suspended by an isotropic Si etching (HNA, 10% HF: 70% HNO_3=1:1). Multimode resonances in liquid (up to 5MHz) are characterized using laser interferometry[6], based on which the piezoelectric driving frequencies are switched in real-time to strongly excite the microspheres and manipulate them into a series of Chladni patterns. Such SiC resonating platform, by taking advantage of its straightforward device fabrication and engineerable multimodes, offer new means for microparticle manipulation and patterning, and may further facilitate cell manipulation, and other biophysical and biomedical studies.

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[5] M. Dorrestijn, *et al.*, *Phys. Rev. Lett.*, vol. 98, no. 2, pp. 026102, 2007.

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