MEMS and NEMS Group
Room On Demand - Session MN-Invited On Demand
MEMS and NEMS Invited On Demand Session

MN-Invited On Demand-1 Printed and Biodegradable Sensors for Real-Time High-Spatial Density Monitoring of Soil Conditions*, Gregory Whiting, Y. Sui, M. Atreya, G. Marinick, J. Nielson, A. Gopalakrishnan,* University of Colorado Boulder*; R. Khosla, S. Dahal, W. Yilma,* Colorado State University*; A. Arias, C. Baumbauer, M. Payne, D. Wong, P. Goodrich,* University of California Berkeley **INVITED**

An understanding of soil properties are of critical importance for optimizing agricultural input use (such as irrigation water and fertilizer) and for general land management strategies. However, obtaining information about soil properties in real-time can be a challenge, which limits management approaches, and can lead to excess input and energy use, reduced profitability, and environmental concerns. Remote imaging can provide high-resolution, but measurements may be infrequent, impacted by weather and plant growth, and could requires inference to determine properties of interest. Installed sensors that directly sample soil can directly provide the desired information directly, but are often bulky and expensive, limiting their use to a small number of sensors per field. This is a concern since many important species of interest (such as soil nitrate), can vary significantly (on the order of 10s of meters), as such, ideally, higher spatial density measurements are needed to capture current conditions and enable optimized management strategies.

In this presentation a number of devices (capacitive, ion-selective, and enzyme/microbe selective) recently developed for real-time, in-situ, high-spatial density monitoring of soil conditions such as moisture and ion (particularly nitrate) concentration, and microbial activity will be discussed. In order to enable broad distribution of large numbers of devices over large areas, these sensors are fabricated using additive printing techniques (such as screen printing) and biodegradable materials for substrates, conductors, encapsulants, stimuli-responsive materials, etc.), so that the sensors degrade harmlessly into the soil when no longer required, enabling large amounts to be used without the need for maintenance or collection or the production of excess waste.

MN-Invited On Demand-7 Chip-scale Atomic Devices*, John Kitching,* NIST **INVITED**

Since the invention of the chip-scale atomic clock in 2001, and its subsequent commercialization in 2011, many research groups and companies worldwide have begun programs to develop similar or related instruments. In this talk, I will present recent work in the Atomic Devices and Instrumentation Group at NIST to develop next-generation devices based on silicon micromachining, atomic spectroscopy and photonics. This will include photonically integrated atomic wavelength references, chip-scale optical clocks and novel atomic diffractive optical elements. I will conclude with a discussion of “NIST on a Chip”, a new effort at NIST to provide low-cost SI calibration at the chip-scale across a range of physical quantities.

MN-Invited On Demand-13 Towards Eliminating Friction and Wear in Micro-Machines to Macroscale Mechanical Systems*, Anirudha Sumant,* Argonne National Laboratory **INVITED**

Every moving mechanical system consisting of contacting/sliding/rotating contacts ranging from nanoscale switches, micro-machines to large macroscale systems such as wind turbines suffers from the energy loss due to wear and friction and it amounts to roughly a quarter of total energy loss worldwide. There is growing demand to develop advanced coatings and lubricants that can not only reduce the energy loss but also last longer, can work in any environment, don’t need replenishment, cheaper to produce on large scale and most importantly are environment friendly. In this context, I’ll discuss our research efforts, which are focused on understanding the atomic scale origin of the friction and how nanoscale interactions of materials at the sliding interface could be manipulated to have its impact on the macroscale. I’ll review our earlier work on demonstrating diamond-based micro-machines with almost no wear even after millions of cycles of operations as it forms impervious tribolayer after initial run-in and some recent work on utilizing a combination of 2D materials and nanoparticles as a solid lubricant in reducing friction and wear to near zero (superlubricity) in rough steel contacts at macroscale. I’ll discuss the underlying mechanism in both cases and how one can translate these fundamental discoveries into real-world applications by working collaboratively with industry.

MN-Invited On Demand-19 Visualization of Nanoscale Contact by in situ AFM-TEM Experiments: Sliding-Dependent Adhesion of Si, and Wear at the Interface MoS2-MoS2 Interface*, Robert Carpick,* University of Pennsylvania **INVITED**

I will discuss nanoscale asperity-on-asperity contact and sliding experiments conducted using an *in situ* nanoindentation apparatus inside a transmission electron microscope (TEM). The instrument has been customized to permit atomic-scale resolution of contact formation, asperity sliding, and adhesive separation of a nanocontact with real-time TEM imaging [1-7], with a new innovation in the instrumentation that allows two AFM tips to be studied in dynamic loaded contact [6, 8]. Forming and separating the contacts without sliding revealed small adhesion forces; sliding during retraction resulted in a nearly 20 times increase in adhesion. These effects were repeatable multiple times. We attribute this surprising sliding-dependent adhesion to the removal of passivating terminal species from the surfaces, followed by re-adsorption of these species after separating the surfaces [8]. Preliminary results from molecular dynamics simulations to elucidate this effect will be discussed. I will also present new results from nanocontact experiments of 2D materials obtained *in situ* using transmission electron microscopy (TEM). We have observed tip-on-tip contact and sliding behavior at the nanoscale for self-mated contacts of few-layer MoS_2, revealing intrinsic contact, adhesion, and friction properties of these ultrathin layers. I will present results comparing the behavior of nanometer-scale thick MoS_2 layers with different degrees of nanocrystallinity, and discuss collaborative work modeling these experiments using molecular dynamics simulations.

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