Tribology Focus Topic
Room: 111 - Session TR-WeA

Emerging Interfaces of Tribological Importance
Moderator: T. Scharf, The University of North Texas

2:00pm **TR-WeA1 Highly Wear-Resistant Surfaces Based on Fluorinated Alkyne-Derived SAMs on Si(111)**, ***S.P. Pujari***, *H. Zuilhof*, Wageningen University, The Netherlands

Micro-electro-mechanical systems (MEMS) are considered to be an important technology for the development of several products in daily life such as electronics, medical devices, and packaging. Even after tremendous progress in fabrication of miniaturized devices based on silicon materials, the development of highly robust surfaces with low friction and resistance against wear is still a challenging subject of accomplishment . To accomplish this goal, new fluorine-containing terminal alkynes were synthesized and self-assembled onto Si(111) substrates to obtain fluorine containing organic monolayers. Such covalently bound organic monolayers have similar surface properties as polytetrafluoroethylene (Teflon), but these monolayers are more stable than traditionally coated PTFE. The combination of these properties yields a highly improved wear resistantance.

A combination of spectroscopic (XPS, IR), microscopic (AFM), and contact angle measurements shows these monolayers were to be ordered and highly hydrophobic. Increasing the amount of fluorine on the alkyne precursor resulted in monolayers with a greatly reduced adhesion to silica probes, as well as an almost 5-fold decrease in the coefficient of friction on the surface. Overall, this yields a friction coefficient that is – to the best of our knowledge – lower than reported for any other fluorine-containing monolayer. In addition, these fluorinated monolayers displayed no sign of wear at high loads. Therefore, the use of such highly durable fluorine-containing monolayers can significantly expand the range of applications for MEMS. Therefore, this work opens a route to design new materials with tailor-made properties for a wider range of applications in MEMS-based devices.

2:20pm **TR-WeA2 Composition and Friction Analysis of Copolymer Solution Treatments of Silicone Hydrogel Contact Lens Surfaces**, ***S. Perry***, *Y. Huo*, *A. Rudy*, University of Florida

The surface chemical compositions of three major brands of silicone hydrogel (SH) contact lenses were analyzed using X-ray photoelectron spectroscopy (XPS) prior to and following treatment in a test solution of diblock copolymer of polyethylene oxide and polybutylene oxide. Atomic force microscopy (AFM) was also employed to evaluate the surface topography and frictional properties of these lenses prior to and following similar solution treatments.For surface compositional analysis with XPS, lens surfaces have been prepared through a vacuum drying procedure, in which the hydrogel is taken from a fully hydrated state directly to an ultraclean, ultrahigh vacuum environment. Contact and tapping mode AFM were used to measure the frictional and topographical properties in aqueous environments. Prior to treatment, differences in surface elemental composition of the various lenses were found to reflect known bulk compositions and/or respective surface treatments. Following solution treatment, surface chemical modifications were apparent in balafilcon A (PureVision®) and lotrafilcon B (O_2 OPTIX®), especially in the distribution chemical functionalities present at the surface. Only modest changes in surface composition were observed for the senofilcon A (ACUVUE® Oasys®) system. AFM measurements in saline revealed large disparities between the coefficients of friction of the three lenses, with balafilcon A and lotrafilcon B exhibiting coefficients of friction approximately five times greater than that of senofilcon A. Lens surface treatment with the diblock copolymer test solution produced a significant reduction in the coefficients of friction of the two lenses exhibiting higher friction, yet only a small reduction in friction was observed for senofilcon A lens. Together, these results depict a strong correlation between the surface chemistry and frictional response of the lens systems as they relate to solution treatment with this specific diblock copolymer. This study indicated that diblock copolymers containing polyethylene oxide and polybutylene oxide may have a positive impact on the lubrication and wetting properties of silicone hydrogel lenses.

2:40pm **TR-WeA3 In Situ Studies of Cartilage Microtribology**, ***D.L. Burris***, *E.D. Bonnevie*, *V.J. Baro*, *L. Wang*, University of Delaware **INVITED**

The progression of local cartilage surface damage toward early stage osteoarthritis (OA) likely depends on the severity of the damage and its impact on the local lubrication and stress distribution in the surrounding tissue. It is difficult to study the local responses using traditional methods; *in-situ* microtribological methods are being pursued here as a means to elucidate the mechanical aspects of OA progression. While decades of research have been dedicated to the macrotribological properties of articular cartilage, the microscale response is unclear. An experimental study of healthy cartilage microtribology was undertaken to assess the physiological relevance of a microscale friction probe. Normal forces were on the order of 50 mN. Sliding speed varied from 0 to 5 mm/s, and two probes radii, 0.8 mm and 3.2 mm, were used in the study. *In-situ* measurements of the indentation depth into the cartilage enabled calculations of contact area, effective elastic modulus, elastic and fluid normal force contributions, and the interfacial friction coefficient. This work resulted in the following findings: 1) at high sliding speed (V=1-5 mm/s), the friction coefficient was low ($\mu = 0.025$) and insensitive to probe radius (0.8 mm – 3.2 mm) despite the 4-fold difference in the resulting contact areas; 2) The contact area was a strong function of the probe radius and sliding speed; 3) the friction coefficient was proportional to contact area when sliding speed varied from 0.05 mm/s-5 mm/s; 4) the fluid load support was greater than 85% for all sliding conditions (0% fluid support when V=0) and was insensitive to both probe radius and sliding speed. The findings were consistent with the adhesive theory of friction; as speed increased, increased effective hardness reduced the area of solid-solid contact which subsequently reduced the friction force. Where the severity of the sliding conditions dominates the wear and degradation of typical engineering tribomaterials, the results suggest that joint motion is actually beneficial for maintaining low matrix stresses, low contact areas, and effective lubrication for the fluid-saturated porous cartilage tissue. Further, the results demonstrated effective pressurization and lubrication beneath single asperity microscale contacts. With carefully designed experimental conditions, local friction probes can facilitate more fundamental studies of cartilage lubrication, friction and wear, and potentially add important insights into the mechanical mechanisms of OA.

4:00pm **TR-WeA7 "Going No Wear?"**, ***W.G. Sawyer***, University of Florida **INVITED**

There is a need for the development of wear-resistant, low-friction materials, and understanding the fundamental origins of wear across length scales will be necessary to guide the development of such materials. The events at buried interfaces that lead to wear entail extreme variability in interaction strength, contact duration, and frequency of occurrence. It has been long postulated that the ensemble of these transient interactions at weak buried interfaces ultimately lead to the ever-present macroscopic phenomena of wear. The quest to find high performance solid lubrication solutions continues. Traditional solid lubrication techniques rely on a pre-deposited coating of a lubricous and/or a protective material, but since these materials wear during operation, the life of the system is finite. In order to extend the operational life indefinitely and to potentially negate any mechanical contributions to wear, a stable lubricating tribofilm of sufficient chemistry and thickness must be maintained during operation. However, because sliding occurs in a buried interface, it has proven challenging to determine what materials processes are actively enabling stable performance and/or what to add to the system to improve lubrication. In this talk, results from a number of ultra-low wear systems (polymers, metals, and ceramics) that have been studied using a variety of active and *in situ* tribological instrumentation will be presented, along with a discussion of the various mechanisms that we believe to be responsible for this unique behavior.

5:00pm **TR-WeA10 Study on the Fatigue Wear Behaviour of TiN and WC DLC-coated Stainless Steel under Inclined Impact-Sliding Load Tests**, ***Y. Chen***, *X. Nie*, University of Windsor, Canada

WC/C diamond-like carbon (DLC) coatings and Titanium Nitride (TiN) coatings are widely used in industrial machinery and tools. Both of the two coatings have extremely hard surfaces comparing to the stainless steel substrate SS316L. The W: DLC coating gives low coefficients of friction against a number of counterfaces, has relatively high lubricity and resistance to adhesive wear comparing to the TiN coating. In this study, a new method which is called cycled inclined impact-sliding test is introduced and utilized to study the coating durability under a combined force of an Impact force *Fi* and Pressing force *Fp* (*Fi/Fp=200N/400N* and

200N/200N) and the fatigue wear behaviors after up to 1000 cycles impact tests. A 10mm steel (AISI 52100) bearing ball is used as the impact indenter. Due to the low coefficient of friction of W:DLC coating against steel counterface, greater impact cycle was endurable before the failure of the coating when impacted in dry air condition. Under inclined impact and sliding forces, fatigue cracking was first initiated, followed by chipping and pealling of the coatings. The SEM showed that different types of fatigue wear cracks were found which distributed in the different areas (head and tail parts) of the impact scars. Most of those scars, observed by 45º tilted cross-sectional SEM, penetrated the coating and caused hardening of the under layer (interface layer). Material transfer from the indenter ball could also be detected by EDX in some areas of the impact scar on both of the coating materials.

5:20pm **TR-WeA11 Scaling Laws of Structural Lubricity for Amorphous and Crystalline Nanoparticles**, *D. Dietzel, T. Moenninghoff, M. Feldmann*, Westfaelische Wilhelms-Universitaet Muenster, Germany, ***U.D. Schwarz***, Yale University, *A. Schirmeisen*, Justus-Liebig University Giessen, Germany

In an effort to reduce the friction between sliding components scientists and engineers have developed a multitude of lubrication schemes. One of the most intriguing concepts is referred to as `structural lubricity', where flat surfaces are thought to slide past each other virtually frictionless if their atomic structures are incommensurate. In this talk, we analyze the fundamental mechanisms that govern the area-dependence of friction in extended but atomically flat contacts of dissimilar materials with a particular emphasize on the relation between structure (crystalline vs. amorphous) and friction. The resulting sublinear power laws, which link mesoscopic friction to atomic principles, are then confirmed by measuring the sliding resistance of gold and antimony particles on graphite [1,2]. The findings suggest that engineering surfaces with unprecedented low friction can be realized.

[1] A. Schirmeisen and U. D. Schwarz, ChemPhysChem 10 (2009) 2358

[2] D. Dietzel et al., Physical Review Letters 101 (2008) 125505

5:40pm **TR-WeA12 Auger Surface Analysis of Deposits Formed on Magnetic Tape Recording Head Surfaces**, ***F.E. Spada***, University of California, San Diego, *D.F. Paul, J.S. Hammond*, Physical Electronics

The 2008 International Magnetic Tape Storage Roadmap[1] projects that the total magnetic spacing between the recording head and the tape magnetic layer must decrease from the current 43 nm spacing to about 23 nm by the year 2018 in order for tape to maintain its cost advantage as an information storage medium. Because tape drives are contact recording systems, interactions between head materials and components in the tape magnetic layer can detrimentally affect the head-tape separation via deposit formation on head surfaces as well as preferential erosion of critical recording head elements. Understanding the nature of these interactions is therefore essential for mitigating undesirable increases in the magnetic spacing. This study shows that deposition and erosion phenomena in tape heads can be varied *at the local level* by changing the electrical configuration of adjacent pole tip structures in multichannel heads, and that the composition of the head deposits depends on the electrical configuration of the pole tips. Using atomic force and electric force microscopy, we show that conductive deposits form on the “trailing edge” of pole tips which are electrically connected to earth ground or to the head substrate. The conductive deposits become non-conductive further “downstream” from the pole tips. Deposits adjacent to electrically isolated poles are always non-conductive. Auger analysis shows that the surfaces of the conductive deposit regions contain high levels of Fe and Co, and small amounts of P and Y, whereas the surfaces of the non-conductive deposits contain predominantly P and Y, with very low levels of Fe. Because all of these elements are present in the magnetic coating of the tape, and because the compositions of the deposits on heads having NiFe pole tips is similar to those on heads having CoZrTa pole tips, these results suggest that the deposits originate from components in the tape and not from metallic structures in the tape head.

1. *International Magnetic Tape Roadmap*, Information Storage Industry Consortium, September, 2008.

*Supported by the Information Storage Industry Consortium Tape Program

Authors Index

Bold page numbers indicate the presenter