Surface Science
Room 203 - Session SS2-TuA
Tribology, Adhesion and Friction

Moderator: K.J. Wahl, Naval Research Laboratory

2:00pm **SS2-TuA1 Temperature Dependence of Nanoscale Friction***, **A. Schirmeisen**, L. Jansen, H. Fuchs,* University of Muenster, Germany

Friction processes at the nanoscale are the focus of numerous research projects, yet a comprehensive picture is still lacking. Despite the fact that most of the proposed models for energy dissipation in point contacts inherently depend on the sample temperature, this issue has been rarely addressed in experimental work. In this contribution we present nanoscale friction experiments with an ultrahigh vacuum atomic force microscope (AFM), where the sample temperature was varied by two orders of magnitude from 30 K to 300 K. Two different materials have been investigated: Graphite and silicon. On HOPG graphite atomic scale "stick-slip" is typically observed. Tribological properties of silicon contacts are of great interest in the area of MEMS/NEMS technology, where friction and wear are an important issue for the technical application of these devices. On graphite the overall friction increases monotonically when lowering the sample temperature. This behaviour can be understood in the framework of atomic scale "stick-slip" friction. The temperature influences the probability of the tip to jump between adjacent potential minima, in effect causing friction to decrease with increasing temperature.@footnote 1@ In contrast, the friction temperature curves on silicon show a rather complex behaviour, with a pronounced friction maximum at 100 K. Similar peaks have been found before in experiments, where internal friction properties of macroscopic vibrating silicon membranes were measured@footnote 2@ Those so-called "Debye-peaks" are related to thermally activated creation of defects in the bulk material, which leads to a strong enhancement of energy dissipation at the Debye temperature. We will discuss some of the intriguing similarities between our nanoscopic friction measurements and the concept of the Debye-peaks in bulk material. @FootnoteText@ @footnote 1@ Sang et al., Phys. Rev. Lett. 87 (2001) 174301@footnote 2@ Berry and Pritchet, J. Appl. Phys. 67 (1990) 3661.

2:20pm **SS2-TuA2 Capillary Adhesion and Tribology involving Adventitious Water on SiOx Surfaces***, **J.E. Houston**,* Sandia National Laboratories

Thin water films adsorbed on surfaces are very important in interfacial interactions and can be critical in determining the behavior and stability of MEMS and NEMS-type devices, which are dominated by extremely high surface to volume ratios. In this presentation, the results of a study are discussed concerning the interfacial interaction of a silica tip and an O-H terminated SiOx surface as a function of both temperature and relative humidity. The study utilizes Interfacial Force Microscopy (IFM) and involves measurements of the normal and frictional forces as a function of interfacial separation. The results indicate, even at very low humidities, that the force profiles are characteristic of a capillary interaction. In addition, the behavior of the lateral force shows significant levels of friction upon capillary formation, increasing further as the two surfaces approach. Upon separating the surfaces, a small hysteretic behavior is observed but with little indication of the "snap-out" instability normally associated with meniscus rupture. These measurements are repeated as a function of tip speed, relative humidity and temperature in order to gain insight concerning the thickness of the water layers, their viscosities and the rates of capillary condensation and evaporation. These results are contrasted with those from similar experiments involving self-assembled monolayer films terminated by combinations of -CH3 and -COOH end-groups. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

2:40pm **SS2-TuA3 Aqueous Based Lubrication: Fundamental Studies of Polymer Brushes Adsorbed at Oxide Surfaces***, **S.S. Perry**, X. Yan,* University of Houston*; N. Spencer, S. Lee, M. Mueller,* Swiss Federal Institute of Technology, Switzerland **INVITED**

The development of synthetic polymer lubricants to mimic joint lubrication within the human body will be presented. Unlike most industrial applications involving oils and greases, lubrication of these joints is accomplished in an aqueous environment. Fundamentally, water is a poor lubricant in most settings due to the weak pressure dependence of its viscosity, yet the contacting surfaces of skeletal joints function with low friction throughout a lifetime. Motivated by the molecular structure of materials making up joint surfaces, interfacial friction between polymer brush surfaces under aqueous environments has been probed with an array of molecularly sensitive surface analytical techniques including atomic force microscopy. The brush surfaces, comprised of poly(L-lysine)-g-poly(ethylene glycol) (PLL-g-PEG), have been generated through the spontaneous adsorption of polymer from solution onto oxide substrates and sodium borosilicate surfaces (AFM tip). The character of the polymer films has been investigated in-situ with the quartz crystal microbalance (QCM) and atomic force microscope (AFM) and ex-situ with ellipsometry and X-ray photoelectron spectroscopy (XPS). The interfacial friction measurements have been carried out on polymer-coated substrates with bare or polymer-coated, microsphere-attached tips in over a range of solution conditions. It was found that the adsorption of polymer on oxides strikingly reduced the interfacial friction, resulting in ultra-low friction under certain conditions. By using a series of PLL-g-PEG polymers differing from each other in PEG side-chain length and grafting ratio, we observed that frictional properties of polymer-coated interfaces strongly depend on the architecture of PLL-g-PEG. Polymer-film formation and the influence of polymer architecture will be reviewed while the role of solvent and manifestation of ultra-low friction will be discussed in detail.

3:20pm **SS2-TuA5 Molecular Dynamics Simulations of the Nanotribological Behavior of a Polytetrafluoroethylene Transfer Films***, **I. Jang**, W.G. Sawyer, S.R. Phillpot, S.B. Sinnott,* University of Florida

Mechanical devices for space applications need to be able to operate reliably in an extreme range of environments. Therefore, the physical and chemical integrity of the materials has to be assured under extremes of both high and low temperature, under ambient pressures and in near absolute vacuum, and under solar radiation. Polytetrafluoroethylene (PTFE) is known to have good thermal and chemical stability, and a low frictional coefficient. Thus polymer nanocomposites based on PTFE are considered to be promising materials for solid lubricant in aerospace applications. Like other polymer materials, many properties of PTFE depend on morphology. By changing the polymeric chain structure and combining it with other materials, it is likely that the frictional coefficient of PTFE can be made lower and its wear resistance further improved. In order to develop new material systems with superior frictional properties or to improve the existing ones, it is necessary to understand the detailed mechanisms of their frictional behavior, and the effect of molecular structure on friction. In this study, molecular dynamics (MD) simulations are performed to examine the effect of chain configuration on the frictional behavior of PTFE at the molecular level, with the aim of identifying the fundamental wear mechanisms, and guiding the further refinement of the materials with low frictional coefficients for space applications.

3:40pm **SS2-TuA6 Correlation of Frictional and Thermal Properties with Molecular Chain Order in Self-Assembled Monolayers of Organosilanes on Silicon***, **S. Sambasivan**,* National Institute of Standards and Technology*; S. Hsieh,* National Institute of Standrads and Technology*; D.A. Fischer, S. Hsu,* National Institute of Standards and Technology

n-Alkyltricholorosilanes films with different chain lengths (Cn films where n=5-30) were characterized by Near edge x-ray absorption fine structure (NEXAFS), FTIR and AFM. The information afforded from these complementary techniques has provided the unique opportunity to interpret the frictional properties of the monolayer films in relation to the molecular assembly and chain lengths. In this study, we use the non-destructive x-ray absorption technique NEXAFS to quantitatively measure the surface (~6nm) molecular orientation of SAMs (self-assembled monolayers). We observe that the chain lengths having 12, 16 and 18 carbon atoms are highly oriented with a preferential molecular orientation of the polymeric C-C chains perpendicular to the surface. C5 and C30 SAMs did not exhibit preferential orientation of the alkyl chain and C10 showed partial ordering. Complimentary FTIR studies were done to estimate order qualitatively by peak positions of asymmetric CH@sub 2@ and the symmetric CH@sub 2@ stretches. The molecular order information from FTIR followed similar trends as determined by NEXAFS. The frictional properties of the organic monolayers were determined through the simultaneous measurement of normal (load) and lateral (friction) interfacial forces with AFM. Friction measurements on different chain lengths follows similar trends with surface order calculated from NEXAFS. In-situ heating and NEXAFS experiments on C16 films reveal that C16 film were well ordered up to 200°C and heating beyond that temperature it transitions from partially ordered to completely disordered/destroyed at 350°C. AFM images show a significant change in surface morphology after annealing. Friction force measurements indicated an increase after heating to 350°C, values approaching close to the friction forces from bare Si wafer.

Our results show that the degree of ordering in the SAM governs the friction properties of the film.

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