Tribology Focus Topic
Room: Southwest Exhibit Hall - Session TR-ThP

Tribology Focus Session Poster Session

TR-ThP1 A Study of Sliding Friction Across Velocity Regimes for Alternative MEMS-type Interfaces using Proximal Probes and Quartz Microbalance, *S. Barkley,* Luther College, *C. Bouxsein, M. Deram, N. Eigenfeld,* St. Olaf College, *L. Matthews,* Luther College, *A. Poda, W.R. Ashurst,* Auburn University, *E. Flater,* Luther College, ***B. Borovsky***, St. Olaf College

As mechanical devices have shrunk to microscopic sizes, the need for a more fundamental understanding of friction and other surface phenomena has become urgent. While the emerging technology of microelectromechanical systems (MEMS) shows promise as the mechanical counterpart to integrated circuits, progress remains slow as structural materials and lubricant strategies continue to be developed. We report on the results of a collaborative effort to study the frictional properties of organic monolayers on metal oxide surfaces. Both a nanoindenter-quartz crystal microbalance (NI-QCM) and an atomic force microscope (AFM) in lateral force mode have been used to perform tribological experiments at sliding velocities spanning the range from microns per second to meters per second. Our initial studies have employed octadecylphosphonic acid self-assembled monolayers chemisorbed onto aluminum oxide components with realistic contact roughness, sizes, and pressures. These interfacial systems have the potential to offer an alternative to silicon-based device fabrication. We present the development of custom microsphere probes for the NI-QCM and AFM systems, as well as the fabrication and characterization of the phosphonate monolayers. We discuss preliminary data from frictional studies across velocity regimes.

TR-ThP2 Deposition and Characterization of TiAlN/WN Multilayer Thin Films Deposited by dc Magnetron Sputtering, ***O. Jimenez-Aleman***, *J. Garcia,* Universidad de Guadalajara, Mexico, *L. Huerta,* Universidad Nacional Autonoma de Mexico, *M. Flores*, Universidad de Guadalajara, Mexico

TiAlN/WN multilayer thin films with a range of different compositions and number of layers were deposited by PVD magnetron sputtering onto a variety of metallic substrates in a mixture of Ar/N_2 atmospheres. The utilisation of different nitride-formers elements and nitrogen (as a reactive gas) allows the deposition of alternative coatings with improved properties (e.g. wear and corrosion resistance) to those observed in individual commercial nitrides. The structure and morphology of the coatings were studied by means of X-ray Diffraction and Scanning Electron Microscopy. The elemental compositions and the surface chemistry (to gain precise information on the bonding environment) of these coatings were obtained by XPS. Microhardness and scratch tests were used to evaluate the mechanical properties and the adhesion of TiAlN/WN thin films respectively. The corrosion resistance was studied by potentiodynamic polarisation experiments in saline solutions of 0.5 M. The tribological properties were studied through reciprocating sliding against ceramic counterparts and different loads. In this paper we report the results relating to the influence of deposition conditions such as deposition temperature, period size and nitrogen content on coating properties. The improvement of corrosion and wear resistance by the utilisation of a multilayered TiAlN/WN arrangement is also presented and discussed.

TR-ThP3 Tribocorrosion Behavior of TiAlN and TiAlN/TiAl Multilayers, ***M. Flores***, *E. Rodríguez, O. Jiménez, J. García,* Universidad de Guadalajara, Mexico, *L. Huerta*, Universidad Nacional Autonoma de Mexico

In the present work we investigate the tribocorrosion behavior of TiAlN, TiAlN/TiAl and TiAlN/TiAl/Pt coatings deposited on 316L stainless steel by magnetron sputtering. The period size of the multilayers was from 250nm to 1350 nm. The friction and wear tests were performed on a ball-on-flat tribometer and conducted in dry (unlubricated) conditions at room temperature. The loads used were 1 to 10 N, the oscillating frequencies were 1-5 Hz. The corrosion was studied using open circuit potential (OCP) measurements and potentiodynamic polarization in ringer solutions. Tribocorrosion tests were performed using a ball-on-flat tribometer where the sliding contact is fully immersed in a Ringer's solution. The potentiodynamic polarizations and OCP measurements were performed during, and after sliding test. The structure and composition of multilayers were studied by means of XRD and XPS techniques respectively. The surface topography and worn surface were studied by means of optical microscopy and profilometry. The results indicate that coefficient of friction (COF) of TIAlN coatings decreased when metal layers are introduced and the corrosion resistance of TiAlN/TiAl coatings is improved when Pt layers are introduced. The synergy effect of the tribocorrosion tests is reported.

TR-ThP4 A Reactive, Fluctuating-Charge Potential for Carbon, Hydrogen, and Oxygen, ***M.T. Knippenberg***, *P.T. Mikulski, J.A. Harrison,* United States Naval Academy

A classical bond-order potential energy function that incorporates fluctuating charges and reactions for carbon-, hydrogen-, and oxygen-containing molecules is presented. The model treats atomic charges as separate degrees of freedom that can be integrated over the course of the simulation, with charge fluctuations arising from the difference in electronegativity in bonds between atoms. Using the bond order that is already calculated, fluctuating charges are equilibrated during the course of the simulation. To test the validity of the potential, the dipole moments of oxygen-containing molecules are examined. Additional tests compare surface energies and structure of oxygen-containing diamond films.

TR-ThP5 Radial Compression Studies of Tungsten Disulfide Nanotubes, ***E. Kalfon-Cohen***, *O. Goldbart, R. Schreiber,* Weizmann Institute of Science, Israel, *D. Barlam*, Ben Gurion University, Israel, *T. Lorenz, G. Seifert*, Technical University Dresden, Germany, *S.R. Cohen*, Weizmann Institute of Science, Israel

Understanding the mechanical properties of nanotubes is of significant practical and fundamental interest. Multiwalled nanotubes and nanoparticles of metal dichalcogenides such as WS_2 express unique mechanical and tribological characteristics.[1] The structure of WS_2 nanotubes consists of layers of covalently bound trigonal bipyramidal WS_2. The interaction between the layers is a van der Waals interaction between adjacent sulfur sheets. One of the intriguing aspects of these structures is the response of these layers under mechanical stress. Whereas some of the elastic constants of these unique structures have been addressed by experimental and theoretical work, the radial compression mode has not yet been studied. Relatively few studies of radial modulus of multiwalled carbon nanotubes have been made, and these also do not explicitly include the multilayered aspect of the structures. Here, we report an experimental and modeling study of this mode in the WS_2 nanotubes.

Three independent atomic force microscope (AFM) experiments were employed to measure the nanomechanical response, using both large (R=200 nm) and small (R=3-15 nm) probe tips. Two different analytical models were applied to analyze the results.[2] For a large AFM tip, a Hertzian model presuming an elliptical contact was applied. A shell continuum model is applied in the case of the sharper AFM tips. This model treats the nanotube wall as a thin, curved membrane. The results indicate that the derived modulus varies with nanotube diameter and compression depth

The modulus values derived from the analytical models were used as initial input for finite element analysis (FEA). The FEA model described the nanotubes as alternating high stiffness (representing the covalent shells) and low stiffness (representing the vdW gap) layers for the outer two shells, with a homogeneous inner core. This model was fit with the experimental results over the initial linear elastic region of the first few nm of deformation. Values obtained varied for different nanotube diameters, and compression depths, showing the importance of the inter-layer contact. In addition, first-principles calculations using density functional theory tight binding give qualitative agreement with a reversible collapse of the nanotubes, seen at larger deformations.

[1] L. Rapoport, et al, *Nature* **387**, 791-93 (1997); I. Kaplan-Ashiri et al, *Proc. Natl. Acad. Sci. USA.* **103**, 523 (2006); I. Kaplan-Ashiri et al, *J. Phys. Chem* **C**. **111** 8432-8436 (2007)

[2] W. Shen, et al, *Phys. Rev. Lett.* **84**, 3634 (2000); M. Minary-Jolandan et al., *J. Appl. Phys.* **103**, 073516 (2008).

TR-ThP6 Tribocorrosion Behavior of nc-TiN/a-Si_3N_4 Nanocomposite Deposited on Metallic Substrates for Biomedical Applications, ***J. García***, *M. Flores, E. Rodríguez, O. Jiménez,* Universidad de Guadalajara, Mexico

The tribocorrosion property of a nc-TiN/a-Si_3N_4 nanocomposite deposited using DC and RF codeposition reactive magnetron sputtering technique on SS316L nitrated and Titanium Ti6Al4V alloy against ceramic and metallic balls was studied in comparison with substrate materials using a reciprocating tribotester in distilled water, 1% NaCl water solution and artificial saliva solution. The effects of load and reciprocating sliding speed on the tribocorrosion properties of the nanocomposite were investigated. The structure and composition of coatings were studied by means of XRD and XPS techniques respectively. Under the experimental conditions of the present study, the nc-TiN/a-Si_3N_4 nanocomposite showed excellent resistance against corrosion and lower wear rate compared with SS316L nitrated and Titanium substrates. Profilometer analysis shows that on both materials most of overall tribocorrosion damage is due to mechanical wear. The tests suggest that nc-TiN/a-Si_3N_4 nanocomposite is a promising biomaterial for applications where reciprocating conditions occur.

TR-ThP8 A Triboligocal Study on Plasma Electrolytic Oxidation Process of Al319, ***H. Eiliat***, *X. Nie*, University of Windsor, Canada

In this study, a plasma electrolytic oxidation process is used in order to produce a layer of oxide on aluminum silicon alloy 316. A pulsed dc power mode with frequencies up to 2000 Hz is selected with current density variations from 0.06 to 1.4 A/cm^2. Surface morphology (roughness), microstructure (grain size) and other properties of the plasma induced layer such as hardness and toughness are studied. Various coating conditions are compared based on treatment time, wear scar and coefficient of friction. These are critical coating properties for automotive engine block applications. The study is concluded by selecting the best coating condition with the optimized thickness.

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