Tribology Focus Topic
Room: Hall B - Session TR-TuP

Tribology Poster Session

TR-TuP1 Study of Charge Separation and Relaxation during Friction between Metal and Plastics in a Vacuum and in Air, ***T. Miura***, National Institute of Occupational Safety and Health, Japan

Electric charges generated by friction, i.e., triboelectricity, between industrial materials induce incendiary electrostatic discharges, such as a spark. In fact, many industrial accidents involving explosions and fires occur due to the electrostatic discharges. In this study, we focus on the elemental processes, e.g., charge separation and relaxation, during friction between metal and plastics. Measurement of the charge separation in a vacuum makes it clear that the real amount of triboelectrification between solid materials because of suppression of charge relaxation through gas discharge in a micro-gap interface of them. In air, we can obtain the relaxation efficiency for the initial charge separation.

The experimental equipment was constructed on the basis of pin-on-disk technique in a vacuum chamber. The pin was made of metal and the disk was made of plastic material. Amount of the separated electric charges between them during sliding friction was measured with an electrometer by connecting to the metal sample.

Experiment with a stainless steel pin and a poly-ethylene terephthalate (PET) disk was performed. The charge density on the rubbed surface of PET was calculated to be about $-5x10^{-4}$ C/m^2 from the generated charges and the width of the friction track. In air, the charge accumulation was, however, one order of magnitude less than the value measured in a vacuum. This should be caused by the charge relaxation as a result of the micro-gap discharge [1].

[1] T. Miura and I. Arakawa, IEEE Transactions on Dielectric and Electrical Insulation, 14, 560-565 (2007).

TR-TuP2 Development of Solid Lubricant Films for Smooth Motion at High Temperatures, ***A. Kasahara***, *M. Sasaki, M. Goto, H. Honda, H. Suzuki, M. Tosa*, National Institute for Materials Science, Japan

Research on low friction materials has attracted considerable attention from the viewpoint of effective energy use for realizing a low carbon society, as these materials can substantially reduce energy loss in bearings, gears, and other mechanical drive parts. However a problem is an increase in friction due to the oxidation reaction in high-temperature environments.

We therefore tried to develop advanced high-temperature motion materials with excellent tribological properties (i.e.: little wear, low friction, good lubrication) in order to guarantee a smooth sliding motion over long periods. Our final purpose is to design coatings suitable for smooth sliding motion up to 1073K.

As a first step, In order to measure friction at high-temperatures exceeding 673K, we designed and manufactured a prototype of a high temperature tribological evaluation device, For this purpose high-temperature friction measurement system based on Bowden-Leben type system has been successfully developed that can evaluate sliding friction force under changing load from 9.8N to 0.098N and under changing heat temperature from 1073K to room-temperature.

We have investigated solid lubricant coatings in order to develop high performance motion mechanism at high-temperature. In previous work, we developed high temperature lubricating coatings by precise control of coating processes using ceramics such as copper oxide, zinc oxide, boron nitride, etc. This time, we focused Cr_2O_3, since this material has been reported to be suitable at high-temperature, but not well been investigated for industrial application to sliding parts.

We have carried out basic study of SUS304, SUS440C and SUJ2 to find out suitable friction parameter at high-temperature from 973K to room-temperature. Their tribological characteristics at high-temperature was evaluated by high-temperature friction measurement system , abrasion measurements by Stylus Surface Profiler and Micro Slurry-jet Erosion.

TR-TuP3 Wear and Oxidation Behaviors of Ti(C, N, O) Coatings, *J.H. Hsieh*, ***Y.R. Cho***, Ming Chi University of Technology, Taiwan, Republic of China

It has been known that the life time of Ti-based hard coatings is dependent on the oxidation rate of Ti. Here, Ti(C,N,O) coatings prepared by a unbalance magnetron sputtering were studied and compared using a static oxidation approach as well as a pin-on-disc tribometer. Ti(C,N,O) thin film prepared with different N2/O2 flow rates were deposited on M2 steel substrates. The films properties were analyzed by Raman spectroscopy, SEM and X-ray Diffraction. These samples then went through static oxidation and tribological testing. The surface morphology and the thickness of oxidation layer were obtained by using scanning electron microscopy (SEM).

In static oxidation, the formed titanium oxide (TiO2) was found to have mainly anatase structure at temperatures between 500ºC to 600ºC and transform to rutile structure at temperature higher than 600ºC. Through this study, oxidation rate and activation energy of oxidation for each sample were evaluated. It is found the samples exhibited higher activation energy could have higher oxidation resistance. These results are consistent with those obtained from wear testing.

TR-TuP4 Multi-Scale Simulation of Ohmic Contact Deformation in RF-MEMS, *C.R. Freeze*, ***X. Ji***, *B.E. Gaddy, D.L. Irving*, North Carolina State University

"Ohmic" RF-MEMS are radio frequency Microelectromechanical Systems (RF-MEMS) switches relying on metal-metal contact. They are of great interest to the telecommunications and defense industries due to their potential for use in switching networks, low-noise/power circuits, portable wireless systems, phased arrays, filters, and antennas. Issues with reliability, however, have prevented widespread commercial use of these devices. In an effort to better understand important degradation mechanisms in the vicinity of the contact, we simulated the complicated environment at the electrical contact through implementation a multi-scale method. This method incorporates an overlay of a finite difference mesh on top of a traditional molecular dynamics simulation. Thermal and electric transport equations are solved via finite difference part of the method and the results are coupled to an underlying atomistic simulation. In this work, contact deformation of ohmic RF-MEMS was approximated as the indentation of a single-asperity on a variety of substrates. These substrates included polycrystalline gold, polycrystalline gold with a void and polycrystalline gold with a trapped pocket of contamination. Indentation was performed for a variety of pressures and applied voltages. The different structures of the substrate result in drastically different steady state thermal profiles when voltage was applied. This significantly affected the indentation depth as compared to room temperature no voltage cases. Flow stress calculations as a function of bulk temperature were used to provide insight into trends in indentation depths as a function of load and underlying structure of the substrate.

TR-TuP5 Effects TiN and TaN Barrier Layers on the Emergence of Ag and Cu Particles and the Subsequent Mechanical and Antibacterial Properties of TaN-(Ag,Cu) Nanocomposite Films, *J.H. Hsieh, Y.R. Cho*, ***Y.H. Lie***, Ming Chi University of Technology, Taiwan, Republic of China

TaN–(Cu,Ag) nanocomposite films were deposited by reactive co-sputtering on Si(001) and M2 tool steels. Prior to annealing, the films were deposited with a barrier layer of TiN or TaN (with various thickness) in order to control the amount of emerged Ag and Cu particles. As a result, the tribological and anti-bacterial behaviors can be controlled. The films were then annealed using RTA (Rapid Thermal Annealing) at 200 °C–400 °C to induce the nucleation and growth of metal particles. Thes films' structures, surface morphologies, and mechanical properties were analyzed. The samples were tested for their anti-wear and anti-bacterial behaviors against Gram-negative Escherichia coli, as function of barrier layer thickness. It is found that, through the application of diffusion barrier, the antibacterial efficiency against E. coli as well as the tribological properties can be changed and controlled, depending on the layer thickness of TiN and TaN. In general, the films with TiN layer tended to allow more Ag and Cu particles to form on the surface.

TR-TuP6 Study of the Wear Mode in Tribocorrosion Tests of CoCrMo Alloys Coated with TiAlN/TiAl Multilayers, ***M. Flores***, *O. Jimenez, E. Rodriguez,* Universidad de Guadalajara, México, *C.E. Canto, E. Andrade*, Universidad Nacional Autónoma de México

The tribocorrosion phenomenon is present in biomedical alloys that are used in artificial implants to replace natural joints. This damage limit the service life of such implants, the hard coatings can improve the resistance of wear and corrosion. The multilayers of TiAlN/TiAl were deposited on CoCrMo alloys by magnetron sputtering. The structure of coatings was studied by means of XRD and the composition by RBS and EDS techniques. The tribocorrosion behavior of CoCrMo alloys alone and coated with TiAlN/TiAl multilayers was studied in simulated body fluid. The tribocorrosion was performed using a ball on plate reciprocating tribometer, the test was conducted in a simulated body fluid at 37 °C of temperature. The loads used were between 0.25 N to 2N, the oscillating frequencies was

1Hz. The corrosion and tribocorrosion were studied using open circuit potential (OCP), potentiodynamic polarization, cyclic polarization and potentiostatic polarization measurements. The potentiodynamic polarization was used to estimate the change in the corrosion rate due to wear and the potensiostatic polarization in the passive region to measure the change in the wear rate due to corrosion. In order to study the wear mechanisms, the topography and composition of worn surfaces were analyzed by means of profilometry, SEM and EDS. For the CoCrMo alloy the corrosion augmentation factor was greater than the wear augmentation factor. The coatings improve the corrosion and tribocorrosion resistance of CoCrMo alloys.

TR-TuP8 Shape-dependent Adhesion and Friction on Au Nanoparticles Studied using Probing Atomic Force Microscopy, ***Y.J. Yuk***, *J.W. Hong, S.W. Han, J.Y. Park*, KAIST, Republic of Korea

Shape control of metal nanocrystals has broad applications, including catalysis, plasmonics, and sensing. It was found that controlling the atomic arrangement on metal nanocrystal surfaces affects many properties, including the electronic dipole or work function. Tuning the surface structure of exposed facets of metal nanocrystals was enabled by shape control. We investigated the effect of shape on nanomechanical properties, including friction and adhesion forces. Two nanoparticles systems, high-index {321} and low-index {100}, were used as model nanoparticle surfaces. Scanning force microscopy was used to probe nanoscale friction and adhesion. Because of the abundant presence of high-density atomic steps and kinks, high-index faceted nanoparticles have a higher surface energy than low-index faceted cubic nanoparticles. Due to this high surface energy, high-index faceted particles have shown stronger adhesion and higher friction than low-index nanoparticles. We discuss the results in light of the differences in surface energy as well as the effect of capping layers in the measurement.

TR-TuP9 Effect of Plasma Nitriding Treatment Time on the Tribology of Tool Steels, ***P. Abraha***, Meijo University, Japan, *J. Miyamoto*, Toba National College of Maritime Technology, Japan

The effect of the plasma treatment time on the formation of the hard but brittle compound layer and the subsequent change on the tribological properties of the tool steel surface were investigated. The nitriding of tool steel was performed in electron beam excited plasma using neutral and charged nitrogen species. The tribological experiments were carried out at room temperature using a pin on disc tribometer. The results show that the tool steel nitrided by neutral nitrogen species for six hours produced , based nitrided layer up to 40 µm, without altering the pretreatment surface finish, Ra=14nm. The specific wear rate was less than one hundredth, 4.3×10^{-7} mm^3/Nm that of the untreated sample. On the other hand, the samples produced by the charged nitrogen species, ions, produced rough and brittle compound layer on the surface. Consequently, the friction coefficient of the former showed slightly lower friction coefficient compared to that of the latter. The results demonstrate that neutral species based nitriding is effective for high performance precision mechanical components that require better friction and wear performance while keeping the as finished pre-treatment dimensional accuracy, surface roughness and appearance of the sample.

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