Tribology and Mechanics of Coatings and Surfaces
Room Palm 3-4 - Session MC1-2-FrM

Friction, Wear, Lubrication Effects, & Modeling II
Moderator: Klaus Boebel, Oerlikon Surface Solution AG, Liechtenstein

8:20am **MC1-2-FrM-2 Active Friction and Wear Control in a-C:Cr Films: Electrical Current and Polarity Effects on Catalytic Graphitization**, ***Newton K. Fukumasu [newton.fukumasu@usp.br]***, *Miguel R. Danelon,* University of São Paulo, Brazil*; Abrar Faiyad, Ashlie Martini,* University of California Merced, USA*; Cherlio Scandian,* Federal University of Espirito Santo, Brazil*; Roberto M. Souza,* University of São Paulo, Brazil

Diamond-Like Carbon (DLC) films are established protective coatings for severe contact conditions, yet their tribological response under active electrical currents involves under-explored physical mechanisms. This study investigates the friction and wear behavior of Cr-doped (a-C:Cr) and undoped a-C films under reciprocating sliding with simultaneous electrical current passage. Tests were performed in dry conditions, using AISI 52100 steel balls against coated glass substrates under anodic (positive plane) and cathodic (negative plane) polarizations, applying a 10 N normal load, 4 mm stroke, and a constant current of 100 mA for the electrified cases. While undoped DLC exhibited inert behavior, resulting in a friction coefficient (COF) of 0.15 regardless of electrical conditions, Cr-doped films demonstrated a friction reduction, down to 0.05, and significant responsiveness to the applied current. Although instrumented indentation and microscopy indicated slightly lower hardness and more visible wear marks for a-C:Cr compared to the undoped film, the tribological behavior is attributed to a local shear-induced phase transformation mechanism. Raman spectroscopy of the a-C:Cr wear tracks under cathodic polarization revealed an intense 2D peak, characteristic of ordered, multilayer graphene-like structures. This result provides evidence that Cr catalytically lowers the activation energy for graphitization, activated by local heating and electron flow. Conversely, anodic polarization resulted in clean wear tracks and stable low friction, suggesting a distinct equilibrium between tribofilm formation and oxidative removal. Reactive Molecular Dynamics simulations supported these findings, elucidating atomistic pathways where Cr clusters facilitate bond rehybridization under combined shear and electrochemical stress. These results demonstrate that the tribological performance of a-C:Cr can be actively tuned, enabling "on-demand" low-friction regimes through electrically assisted catalytic graphitization.

8:40am **MC1-2-FrM-3 Tribological Performance of Sputter-Deposited MoS_2 Coatings with Varying Process Gases**, ***Tomas Babuska [tfbabus@sandia.gov]***, *Alexander Mings, Steven Larson, John Curry, David Adams,* Sandia National Laboratories, USA

Sputter-deposited molybdenum disulfide (MoS_2) coatings have been used for decades in aerospace applications due to their ultra-low steady-state coefficients of friction ($\mu_{ss} < 0.05$). Developing MoS_2 coatings for demanding applications with predictable and reliable performance over time (i.e., high-quality) requires tuning the coating microstructure through process variations. In this work, we explore process-structure-property-performance relationships of pure MoS_2 solid lubricant coatings where coatings are sputter deposited using different process gases. Helium, kypton, neon, argon and xenon are used to sputter deposit MoS_2 of varying morphologies, and the impact on critical performance traits such as initial friction, run-in, and aging resistance are studied. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

9:00am **MC1-2-FrM-4 Effect of Ta Content in ta-C:Ta Coatings on the Machining Performance of Aluminum Alloy**, ***Kosuke Suzuki [kousukes@mmc.co.jp]***, Mitsubishi Materials Corporation, Japan*; Takayuki Tokoroyama, Ruixi Zhang, Noritsugu Umehara,* Nagoya University, Japan*; Shun Sato, Kenji Yumoto,* Mitsubishi Materials Corporation, Japan **INVITED**

In recent years, demand for lightweight materials in the automotive and aerospace industries has increased, leading to a growing need for machining aluminum alloys. In aluminum alloy machining, Diamond-Like Carbon (DLC) coatings—especially hydrogen-free tetrahedral amorphous carbon (ta-C) coatings—are widely used due to their excellent wear resistance and low friction, which help suppress material adhesion and tool wear caused by hard Si particles in the alloy.

However, under more severe machining conditions, further improvements in coating performance are required to extend tool life, especially in terms of wear resistance and delamination resistance. One of the representative approaches for such performance enhancement is the addition of transition metal elements to DLC coatings, and numerous studies have been reported in this area. Among these, tantalum (Ta) is known to form strong covalent bonds with carbon and is expected to achieve both mechanical strength and improved adhesion strength through the reduction of residual compressive stress.Nevertheless, studies on its influence on machining performance remain limited.

In this study, tantalum-doped ta-C (ta-C:Ta) coatings with varying Ta contents were fabricated, and the correlation between Ta content and coating properties, as well as its effect on the drilling performance of aluminum alloy (ADC12), was systematically evaluated.

For each coating, microstructural analysis and residual stress measurements were conducted, along with ball-on-disk friction tests and scratch tests. Additionally, aluminum alloy cutting tests were performed to evaluate wear resistance and cutting force. As a result, the friction coefficient and specific wear rate tended to increase with higher Ta content in the friction tests. On the other hand, the scratch tests showed an increase in critical load, and a correlation between critical load and residual compressive stress was confirmed. Observations of the scratch marks revealed that ta-C:Ta coatings exhibited smaller delamination areas compared to undoped ta-C coatings. The dispersed structure of TaC nanocrystals observed in the ta-C:Ta coatings is suggested to suppress delamination propagation and contribute to improved toughness.

In the cutting tests, the coating containing 1.1 at.% Ta demonstrated the best wear resistance and lowest cutting force by significantly suppressing chipping while maintaining resistance to abrasive wear. These results suggest that controlling residual stress through appropriate Ta addition and enhancing toughness via fine TaC structures are effective strategies for improving tool life in aluminum alloy machining.

10:20am **MC1-2-FrM-8 Effects of Silver Nitrate Additives on the Antibacterial and Corrosion Behaviors of Plasma Electrolytic Oxidized AZ31 Magnesium Alloy**, ***Bo-Xuan Zheng [rick910823@gmail.com]***, *Chuan-Ming Tseng,* Ming Chi University of Technology, Taiwan, Republic of China

AZ31 magnesium alloy exhibits excellent biodegradability and biocompatibility, making it a promising candidate for temporary biomedical implants. Nevertheless, its rapid degradation and insufficient corrosion resistance severely limit its direct clinical application. In this study, the bioceramic composite coatings on AZ31 magnesium alloy were prepared by using plasma electrolytic oxidation (PEO) under bipolar power mode in alkaline solutions with sodium phosphate, sodium silicate, potassium fluotitanate and silver nitride ($AgNO_3$) additions. The effect of $AgNO_3$ content on antibacterial and corrosion behaviors of PEO coatings on AZ31 magnesium alloy was investigated. The microstructural characterizations of the $AgNO_3$-incorporated PEO coatings were identified by XRD, SEM-EDS and EPMA. The adhesion and wear resistance of PEO coatings were evaluated using scratch testing and pin-on-disk wear tests, respectively. The potentiodynamic polarization measurements were conducted to evaluate the corrosion behaviors of PEO coatings in simulated body fluid (SBF) solutions. The antimicrobial properties of PEO coatings were carried out by measuring the numbers of *Escherichia coli* bacterial colony after various incubation durations. The XRD patterns reveal that the PEO coatings are mainly composed of MgO (inner layer) and Mg_2SiO_4 (outer layer). Cross-sectional SEM–EDS mapping images confirm that Ag elements are well dispersed near surface of PEO coatings. The highest adhesion strength (~36 N) and the lowest wear rate (5.5×10^{-6} mm^3/N m) can be achieved for the PEO coating with 0.2 g/L $AgNO_3$ incorporated. However, the potentiodynamic polarization curves display that the PEO coatings, as compared to AZ31 magnesium alloy, exhibit higher corrosion resistances in SBF solutions. Furthermore, the PEO coating with 0.2 g/L $AgNO_3$ addition shows the optimal corrosion resistance due to its lowest corrosion current density (1.07×10^{-8} A/cm^2). Furthermore, the antibacterial efficiency of the PEO coatings is significantly improved with increasing $AgNO_3$ additives. More interestingly, all the PEO coatings with various $AgNO_3$incorporated exhibit a 100% antibacterial efficiency to *Escherichia coli* after incubation in 45 minutes. In summary, the adhesion, wear resistance, antibacterial efficiency and corrosion resistance of PEO coatings on AZ31 magnesium alloy can be pronouncedly improved by $AgNO_3$ additions, highlighting their potential for biodegradable implant applications.

Keywords: PEO, AZ31, Silver nitrate, Corrosion resistance, SBF.

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