Tribology and Mechanical Behavior of Coatings and Engineered Surfaces

Room Town & Country B - Session E1-1-TuA

Friction, Wear, Lubrication Effects, and Modeling I

Moderators: Noora Manninen, Oerlikon Balzers, Oerlikon Surface Solutions AG, Liechtenstein, **Prof. Dr. Andreas Rosenkranz**, Universidad de Chile, **Dr. Manel Rodriguez Ripoll**, AC2T Research GmbH, Austria

1:40pm **E1-1-TuA-1 Chemistry and Mechanical Properties of 2D Transition Metal Carbides and Carbonitrides (MXenes)**, ***Vadym Mochalin,*** University of Missouri S&T, USA **INVITED**

A large family of two-dimensional transition metal carbides and nitrides (MXenes) raises interest for many applications due to their high electrical conductivity, mechanical properties [1], potentially tunable electronic structure [2], nonlinear optical properties [3], and the ability to be manufactured in the thin film state [4]. However, their chemistry that is key to development of these applications, still remains poorly understood [5-8]. In this presentation we will discuss recent progress in understanding fundamental MXene chemistry and harnessing it for suppressing unwanted reactions and prolonging stability of these materials.

Mechanical properties of MXenes, including their adhesion to other materials, 2D materials, and other MXenes will be discussed. Adhesion plays an important role in assembly of 2D heterostructures. Data on tribological properties of MXenes, including superlubricity, will also be presented and discussed.

Selected examples illustrating connections between MXene chemistry and their mechanical properties will also be considered.

References

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2:20pm **E1-1-TuA-3 Tribocorrosion Behaviours of VNbMoTaWCr High Entropy Alloy Coatings**, ***Ismail Rahmadtulloh,*** *C. Wang, W. Wang,* National Taiwan University of Science and Technology, Taiwan*; B. Lou,* Chang Gung University, Taiwan*; J. Lee,* Ming Chi University of Technology, Taiwan

Recently, tribocorrosion has become an interesting research topic for academic researchers and industries. The deep understanding of tribocorrosion behaviour has become important in development of alloys having good wear resistance and corrosion protection. In this work, four VNbMoTaWCr high entropy alloy (HEA) coatings with different Cr contents were fabricated by a pulsed DC magnetron sputtering system. For tribocorrosion tests, the HEA coatings were immersed in a 3.5 wt.% NaCl aqueous solution at room temperature under 1 N load using a pin-on-disk tribometer. The potentiodynamic polarization tests were performed to investigate the corrosion potential, corrosion current density, and polarization resistance for each coating before and during the tribocorrosion test. The effect of Cr concentrations on the tribocorrosion behaviours of four VNbMoTaWCr HEA coatings was explored. The synergism between wear and corrosion was studied based on ASTM G119 standard. The change of corrosion loss due to wear and the change of wear loss due to corrosion were calculated. The total material loss rate and corrosion-wear map were explored to understand the extent of the wear and corrosion augmentation factors. We can find out that the VNbMoTaWCr coating with 11.7 at.% Cr content had the lowest total material loss rate of 9.2162 mm/yr, which is better than that of 304SS, 18.0009 mm/yr. It showed that the transitions between wear and corrosion for four VNbMoTaWCr coatings and 304SS were all lower than 0.1 indicating synergistic effects dominated and corrosion was affecting wear to a great extent than wear was affecting corrosion.

2:40pm **E1-1-TuA-4 Fundamentals of Phototribology**, *B. Perotti,* UCS, Brazil*; A. Cammarata,* Czech Technical University in Prague, Czech Republic*; F. Cemin,* Nantes Université, France*; S. Sales de Mello,* Université Grenoble Alpes, CNRS, France*; L. Leidens,* UCS, Brazil*; F. Echeverrigaray,* UNICAMP, Brazil*; T. Minea,* Université Paris-Saclay, France*; F. Alvarez,* UNICAMP, Brazil*; A. Michels,* UCS, Brazil*; T. Polcar,* University of Southampton, UK*;* ***Carlos Figueroa,*** UCS, Brazil

Friction phenomenon is a ubiquitous manifestation of nature originated in the dissipation of energy after stochastic interactions of particles from two surfaces. There are several ways to set up the friction behavior of tribological systems by means of surface finishing, liquids and gases, all of them nonreversible processes. Thus, the active control of friction through external sources is a challenge in tribology. Electric and magnetic fields were proposed to control friction remotely. It is a new paradigm in tribology where radiation fields can tune friction. In our case, we used a photoactive material (TiO_2) to active control of friction forces at the nanoscale as a function of the presence or absence of UV illumination (λ = 365 nm and variable luminous flux) by friction force microscopy (FFM). We could determine that the light can tune friction forces in a reversible, stable, reproducible and reliable way. The UV light induces surface rearrangements of atoms in a similar way of those processes for degradation of organic molecules on activated TiO_2 surfaces. Indeed, the half-life of the pseudo-first order kinetics is roughly the same of those well stablished degradation processes of organic molecules in aqueous suspension with TiO_2 particles. Moreover, the reduction of friction under UV illumination follows a sigmoidal behavior with the luminous flux. These findings contribute to a new conceptual framework in tribology where light may be defined as a fourth body and the integration of tribology with photonics and optoelectronics providing a promising direction for applications in micro- and nano-opto-electromechanical systems.

3:00pm **E1-1-TuA-5 Ultra-thin nanotwinned $(CoCrNi)_{100-x}$ W_x Medium Entropy Alloy Film: Role of Nanotwin in Mechanical and Tribology Behaviors**, ***Jhen-De You,*** National Taiwan University, Taiwan*; P. Yiu,* Ming Chi University of Technology, Taiwan*; C. Hsueh,* National Taiwan University, Taiwan

A significant amount of materials are lost each year as a result of wear-induced damages. Meanwhile, small-scale medium entropy alloy films (MEAFs) have attracted much attention recently due to their superior mechanical properties over their bulk counterparts. In this work, we aim to investigate the plastic deformation characteristics (hardness, strain rate sensitivity and tribology) and structure evolution of nanotwinned $(CoCrNi)_{100-x}W_x$ (x = 0, 0.9, 3, 5.3, 7.2 and 9.8) MEAFs. The $(CoCrNi)_{100-x}W_x$ MEAFs were fabricated using magnetron co-sputtering. The tungsten content increased from 0 to 22.01 at.% with the increasing power applied on the W target. Microstructures of thin films thus prepared were examined by the atomic force microscope, scanning electron microscope and transmission electron microscope. The structure evolution and mechanical properties were investigated in this work. The W addition in CoCrNi matrix resulted in transition from FCC solid solution to amorphous structure. Nanotwins were observed in FCC grains for $x \leq 9.8$, and the $W_{7.2}$ MEAF showed the thinnest twin thickness of ~1 nm, the superior wear-resistance and hardness, and the lower coefficient of friction via nano-scratch, nano-wear and nano-indentation tests. Although the amorphous $W_{22.01}$ MEAF showed the higher hardness than $W_{7.2}$, its wear resistance was inferior to crystalline $W_{7.2}$ MEAF. Our work demonstrated the structure evolution, mechanical properties, and wear performance of $(CoCrNi)_{100-x}W_x$ MEAFs, also gave insight of wear-mechanism in nanotwinned CoCrNi-based system.

4:00pm **E1-1-TuA-8 Understanding the Tribology Behavior of Carbon Thin Films Deposited by the HiPIMS Technique in Ar+Ne Atmospheres**, ***Cesar D. Rivera Tello,*** Universidad de Guadalajara CUCEI, Departamento de Ingeniería mecánica eléctrica, Mexico*; L. Flores Cova, A. Guerrero de León, J. Pérez Alvarez, M. Flores Martínez,* Universidad de Guadalajara CUCEI, Mexico

This investigation focusses in the effects of using Ne + Ar mixture in the plasma of the HiPIMS discharges in the deposition process of diamond like carbon thin films and in the tribological tests. The plasma deposition process was analyzed by mass quadrupole spectroscopy obtaining the ion energy distribution for C^+ ions from different gas composition discharges

(20, 40, 60, 80, 90 and 100% Ne). Derived from these processes, a carbon thin film was obtained for each gas composition discharge, where the bond-structures of them were analyzed by Raman spectroscopy. The tribology behavior of all the samples was studied by friction coefficients and analyzing the images of the wear track obtained by reciprocating ball-on-plate configuration of the tribological tests. Furthermore, these Ne +Ar mixture thin film were compared to similar films without Ne to observe mainly differences. The results showed slight increment on the ionization with the %Ne gas composition discharge. Besides, a significant reduction of wear in comparison to the films without Ne was shown, derived from lower sp^3 content in the carbon films in comparison to the carbon films without Ne. Finally, we observe a significant increment on the deposition rate for the films deposited with Ne.

4:20pm **E1-1-TuA-9 Effect of Sizing on the Adhesion Properties of Reclaimed Fiberglass Composites***, **Nour Halawani**,* Composite Recycling and LPAC - EPFL, Switzerland*; M. Anderson, P. Gallo, G. Perben,* Composite Recycling, Switzerland*; V. Michaud,* LPAC - EPFL, Switzerland

Recycling Glass Fiber Reinforced Plastics has been a challenge for decades. Currently, the most common solution for composite disposal is landfilling, which is the case for more than 90% of GFRP disposal worldwide. We have developed a thermal treatment based on pyrolysis which separates the fibers from the resin without the need for grinding or chopping the feedstock. The reclaimed fibers are then treated and integrated into new composites. To ensure a clean surface free from carbon impurities, the fibers are treated with a thermal cleaning method. After this process the resin, sizing, and the binder are removed from the surface and thus the surface still has impurities at the microscale which requires further treatment. The treatment of fibers requires additional cleaning, surface activation to increase the density of hydroxyl groups (-OH) on the fiber surface, and sizing application.

Sizing formulations are applied in a thin homogenous coating on fiberglass in the commercial production step. The main reason is to protect the fiber surface during the production and post processing steps while creating different kind of fabrics. Additionally, the sizing is adapted to ensure good adhesion between the fibers and the matrix. In this work we aim to use the reclaimed fibers to produce new composites maximizing the mechanical properties in comparison with the initial composite, while keeping the treatment as minimal and benign as possible. We also aim to valorize the reclaimed fiberglass without losing their length.

For the sizing treatment, we apply two different kinds of sizing based on alkoxysilanes on fiber surfaces in order to study their effect on the adhesion as well as the final mechanical property of the obtained composite. A special combination of surface cleaning, surface activation and sizing application are applied and controlled using SEM and FTIR. The surface of the fibers are seen to be clean homogenously. The flexural strength of the composite made up of untreated reclaimed fibers showed a decrease of 60 % whereas, when applying our surface treatment, we can see an improvement with a decrease of only 5 to 25% depending on the process and the sizing used. The adhesion of the treated fibers to the matrix is controlled using single fiber pull-off test validating our treatment procedure.

4:40pm **E1-1-TuA-10 The Effect of Core Crystallographic Orientation on the Dislocation Dynamics of Core-Shell Nanostructures: A Molecular Dynamics Study***, **Robert Fleming**,* Arkansas State University, USA

Core-shell nanostructures, composed of a metallic core with a hard amorphous shell, are known to exhibit unusual dislocation dynamics which subjected to compression loading. Experimentally, this behavior manifests as substantial deformation recovery beyond the elastic limit, enhanced fatigue resistance, and improved durability. However, the fundamental physical mechanisms that enable the underlying dislocation dynamics in these nanostructures are still poorly understood. In this study, the role of crystallographic orientation of the confined metallic core is investigated for 2 FCC metals (Al, Cu) and 1 HCP metal (Mg), all with a-Si shells. Along with supporting stress calculations, understanding the interplay between crystallographic orientation, active slip systems, and core-shell interface structures will provide insights into the unique mechanical behavior of these nanostructures, with an ultimate goal to design material systems with controllable dislocation dynamics.

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