Tribology and Mechanics of Coatings and Surfaces
Room Palm 5-6 - Session MC2-1-TuA

Mechanical Properties and Adhesion

Moderators: Lin-Li Chia, Ming Chi University of Technology, Taiwan , **Michael Meindlhumer**, Montanuniversität Leoben, Austria, **Balila Nagamani Jaya**, Indian Institute of Technology, India

1:40pm **MC2-1-TuA-1 Mechanical and Interfacial Behavior of Liquid-Like Polymer Surfaces at Extremes***, **Megan J. Cordill [megan.cordill@oeaw.ac.at]**,* Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, Leoben, Austria **INVITED**

Ice buildup presents significant obstacles for both power generation and air transportation in cold regions requiring effective ice protection strategies. Passive anti-icing methods, such as icephobic coatings have garnered increasing interest due to their cost-effectiveness and eco-friendliness. Effective passive ice removal requires very low ice adhesion strength values of less than 20 kPa so that the ice can be easily removed with natural forces such as wind and gravity. Recent studies have shown that liquid-like surfaces (LLS) with ice-shedding properties can be generated through the covalent attachment of linear polymer chains onto smooth substrates bearing sufficiently high hydroxyl group densities. The durable coating retains its slippery properties after exposure to laboratory conditions of icing/deicing and heating cycles, organic solvents, and acid treatment. However, little is known about mechanical stability and longevity of the LLS at relevant temperatures and wind speeds. Nanoindentation, both traditional and AFM-indentation, was used to measure the mechanical properties at various temperatures to establish a ductile to brittle transition of the coating. Additionally, scratch and wear testing were utilized to mimic scratch induced debris and removal of the LLS. As a final check, bulge testing was used to evaluate the adhesion of the ice-phobic coating to the aluminum substrate. These experiments were then compared to the same coatings subjected to various ice and wind tunnel experiments performed on a NACA 0012 aerofoil that would simulate actual conditions during take-off and landing. The combination of assessments demonstrates that the developed LLS coating is robust for wind turbine applications as well as to replace anti-icing fluids currently used for airplanes.

2:20pm **MC2-1-TuA-3 In Situ Observation of Multicracking in Thin Films and Nanostructures***, **Damien Faurie [faurie@univ-paris13.fr]**,* 99 avenue Jean-Baptiste Clément, France **INVITED**

Multicracking in brittle thin films on compliant substrates is a critical reliability issue in flexible electronics, optical coatings, and protective thin-film technologies. While characteristic fracture patterns have been reported for decades, the fundamental mechanisms governing crack initiation, spacing, and multiplication still remain unclear. Classical models link average crack spacing to film thickness, yet they do not account for the local stress heterogeneity and accumulation of damage that precede fracture.In this invited talk, we present an *in situ* experimental methodology that combines synchrotron X-ray diffraction with real-time optical imaging during controlled uniaxial and biaxial mechanical loading of brittle thin films (10–500 nm) supported on polymer substrates. This approach enables the simultaneous monitoring of stress evolution, diffraction peak broadening (FWHM), and crack nucleation. We show that variations in FWHM provide a quantitative diffraction signature of local stress concentration and correlate directly with the onset and multiplication of cracks. This establishes a direct link between microscopic stress heterogeneity and the formation of multicracking networks.Looking forward, we extend this methodology to lithographically patterned thin films, where periodic architectures (e.g., parallel wires, modulated-width structures, multilayered or architectured interconnects) offer new degrees of freedom to tailor stress distribution and confinement effects during deformation. We will discuss how such artificial architectures can promote or suppress crack formation, enable stress redistribution, and ultimately improve thin-film reliability.Overall, this work provides a new framework to understand and engineer multicracking in thin films and opens pathways toward mechanically robust architectured coatings and interconnects for next-generation flexible technologies.

3:00pm **MC2-1-TuA-5 Numerical and Experimental Evaluation of Cyclic Contact Loads on Titanium Borides***, Hugo Alberto Pérez Terán, GERMAN ANIBAL RODRIGUEZ CASTRO, ALFONSO MENESES AMADOR, **Felipe Nava Leana [felnaval@gmail.com]**,* Instituto Politécnico Nacional, Mexico*; Daybelis Fernández Valdés,* Tecnológico Nacional de México*; VICTOR MANUEL ARAUJO MONSALVO,* Instituto Nacional de Rehabilitación Luis Guillermo Ibarra Ibarra, Mexico

In this work a Ti6Al4V alloy hardened by the boriding process was evaluated by cyclic contact loads. Powder-pack boriding process was used to modify the alloy surface where two phases TiB and TiB_2 were obtained on the sample due to the boron diffusion into the substrate material. The thermochemical treatment was carried out at a temperature of 1100°C for 10, 15 and 20 h of exposure time. Titanium borides (TiB and TiB_2) formed on the surface of the Ti6Al4V alloy was confirmed by means of the XRD analysis.Berkovich nanoindentation test was conducted to determine both hardness and Young's modulus of the borided samples. Cyclic contact loads were applied on the borided sample using a MTS Acumen equipment to evaluate the quality of the titanium borides based on the damage caused on the sample surface. Finite element method was used to obtain the stress field due to cyclic contact loads. Results showed that the sample with thicker thickness because of longer treatment time showed the best mechanical behavior under cyclic contact loads.

4:00pm **MC2-1-TuA-8 Grain Boundaries and "Complexions" in Metallic Thin Films: New Insights on the Interplay of Atomic Structure, Chemistry and Material Properties***, **Gerhard Dehm [dehm@mpie.de]**,* Max Planck Institute for Sustainable Materials, Germany **INVITED**

Similar to surface reconstructions, grain boundaries in polycrystalline materials can undergo phase transformations (sometimes referred to as "complexion" in the literature), which alter the resulting properties. Temperature, stress, and chemical composition are the main driving forces for such transformations. Understanding and controlling such transformations allows additional control over the relationships between structure, processing, properties, and performance, especially in materials with a high content of grain boundaries.

The first part of the presentation shows examples of grain boundary phases and transitions in pure and alloyed metallic thin films. Surprisingly, grain boundary phase transitions are observed even in pure metals. The second part of the presentation focuses on electrical and mechanical properties. A workflow is presented that allows to investigate the contribution of individual grain boundary structures to electrical resistivity. The results show that the excess volume of a grain boundary is the main contributor to electron scattering in a pure fcc metal such as copper. However, impurities segregated at the grain boundary can significantly alter electron transport. This can be exploited positively, but can also be detrimental, as exemplified with two examples.

Also mechanical properties are strongly influenced by grain boundaries and their phases. While this has long been known for cases of grain boundary embrittlement, such as Bi in Cu or Ga in Al, the influence on strength and shear-coupled grain boundary motion has only recently been studied in detail and will be presented in the lecture. Finally, strategies to make use of grain boundary "complexions" for property design are discussed.

Acknowledgment: This work gas been partially supported by the ERC advanced grant GB-Correlate (Correlating the State and Properties of Grain Boundaries [https://www.mpie.de/3893203/GB-correlate]) and the German Science Foundation DFG within the SFB 1394 Structural and chemical atomic complexity – from defect phase diagrams to material properties. Fruitful interactions with many colleagues, especially T. Brink, C. Liebscher, L. Langenohl, K. Bhat, A. Kanjilal, J. Duarte, and H. Bishara are gratefully acknowledged.

4:40pm **MC2-1-TuA-10 Many-to-one Mapping Between Stress-Strain Curves and Spherical Indentation Load-Displacement Curves***, **Santosh Thapa [sth230@g.uky.edu]**, Yang-Tse Cheng, Madhav Baral,* University of Kentucky, USA

The stress-strain relationship is key to understanding material behavior, yet conventional tensile testing provides only bulk-averaged properties and fails to capture local heterogeneities. Instrumented indentation testing (IIT), particularly with spherical indenter, is often assumed capable of uniquely determining stress-strain relationships from a single load-displacement curve. However, our results challenge this assumption showing that different combinations of elastic modulus, yield stress, and work-hardening exponent can produce indistinguishable indentation responses, highlighting the non-uniqueness of the inverse problem of obtaining stress-strain relation from spherical indentation load-displacement curves. Thus, the quest for obtaining local mechanical properties from spherical indentation measurements continues.

5:00pm **MC2-1-TuA-11 Tribological Performance and Mechanistic Insights of Aluminium-Sic Composites Fabricated by Computerized Bottom-Pouring Stir Casting***, **Vishal Mehta [mehtavishalr@gmail.com]**,* Automobile Engineering Department, Parul Institute of Technology, India*; Anand Joshi,* Micro Nano Research and Development Center, Parul University, India*; Unnati Joshi,* 3Mechanical Engineering Department, Parul Institute of Engineering & Technology, India

The growing demand of lightweight structural material with enhanced wear resistance has accelerated the study of aluminium based metal matrix composites that are reinforced using ceramic particulates. The composites in the present research were Aluminium-Silicon Carbide (Al-SiC) produced by computerized bottom pouring type stir casting, which has a high level of control on the process parameters giving accurate dispersion of reinforcement and fewer defects in the casting. This work is devoted to the evaluation of the friction and wear properties of the developed composites in the dry sliding mode and to determine the prevalent wear mechanisms by means of the surface and compositional analyses.

In the present investigation, pure aluminium (Al) was considered as a matrix material due to easy availability. Pure Al was reinforced with 5 wt.% SiC having size of 40-50 microns. Rockwell hardness of the developed AMCs were measured and 13% higher values were observed as compared to unreinforced matrix. The pin-on-disc tribometer was used for a tribological test in wet conditions. The Al-SiC AMCs were found to have a significant decrease in the coefficient of friction and wear rate with those of the unreinforced aluminium matrix. The ability of the SiC particles to prevent direct contact between metal and metal contributed to the increased performance and was attributed to the bearing role of the particles. The smoother worn surfaces and reduced scars of adhesive wear were observed post-test SEM analysis, whereas the EDX spectra proved the absence of intermetallic Al_4C_3 in the developed composite with C/Al mass ratio value of ~0.176 referring to theoretical stoichiometric value for Al_4C_3 (~0.334). The EDS result confirms the defect free AMC development for the further applications. The wear mechanisms observed in SEM characterization indicates transition from adhesive wear in the base alloy to mild abrasive and oxidative wear in the reinforced composites.

These findings suggest that computerized bottom-pouring stir casting provides both an effective and quality production pathway to high-integrity Al-SiC AMCs with improved friction and wear properties and therefore promising in surface engineering, tribological finishes and other lightweight component applications.

Keywords

Aluminium matrix composites, Friction and wear, SEM, EDX, Stir casting, Tribology

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