Tribology and Mechanics of Coatings and Surfaces
Room Golden State Ballroom - Session MC-ThP

Tribology and Mechanics of Coatings and Surfaces Poster Session

MC-ThP-1 Role of Layer Position During Thermo-Mechanical Loading of Trilayers*, **Megan J. Cordill [megan.cordill@oeaw.ac.at]**, Claus O.W. Trost,* Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, Austria

Thermo-mechanical loading of thin films on rigid substrates is common method to assess film stresses as a function of temperature. However, these experiments have historically only been performed on single layer films even though multilayers are used in all advanced thin film technology. To illustrate the feasibility of measuring the thermo-mechanically induced stresses of multiple layers simultaneously, different architectures of brittle-ductile-brittle and ductile-brittle-ductile trilayers on silicon were heated with in-situ X-ray diffraction (XRD). The use of XRD provides individual film stress evolution simultaneously to understand delamination mechanisms of the trilayer architecture. The main aspects presented will be the strain evolution under thermo-mechanical loading as a function of layer position. Following Mo and Cu films from next to the substrate, to the middle position, and as the top surface film found that position in the trilayer architecture significantly influences the stress-temperature curve, thus the deformation mechanism due to thermo-mechanical loading.

MC-ThP-4 Nanoindentation and Micropillar Compression at Cryogenic Temperatures*, **Eric Hintsala [eric.hintsala@bruker.com]**, Kevin Schmalbach, Douglas Stauffer,* Bruker Nano Surfaces, USA

Mechanical reliability at low temperatures is required for environments in energy and aerospace applications. Due to its highly localized measurement capabilities, nanomechanical approaches can be useful for isolating individual regions within a more complex microstructure or component or testing of thin films.In general, both modulus and yield strength gradually increase with decreasing temperature,but more sudden shifts in behavior can also be observed, such as phase transformations or ductile-to-brittle transitions. In situSEM testing enables visualization of the deformation mechanisms coupled with the measured mechanical properties helping complete the interpretation of the behavior.Alow temperature control system has been developed for the Hysitron PI89PicoIndenter (Bruker, USA) for in situ SEM testing that enables continuous temperature control from -130°C to 50°C. Independent temperature control on the tip and sample to enable proper temperature matching in vacuum and minimizes drift. The temperature dependent mechanical response of two metallic samples, Nitronic 50 and Tungsten, both by nanoindentation and micro-pillar compression.

MC-ThP-7 Investigating Arctic Environmental Effects on Dry Sliding Wear Behavior of Protective Coatings*, **Elyse Jensen [elyse.jensen@mines.sdsmt.edu]**, Austin McCracken,* South Dakota School of Mines and Technology, USA*; Emily Asenath-Smith,* Cold Regions Research and Engineering Laboratory, USA*; Grant Crawford, Forest Thompson,* South Dakota School of Mines and Technology, USA

Understanding the tribological response of protective coatings to environmental conditions is required in order to tailor their functionality for extreme service conditions. This study establishes a methodology for evaluating the sliding wear performance of protective coatings in conditions representative of Arctic environments. A low temperature ball-on-flat tribometer was modified to enable control over dewpoint within the testing enclosure. CrN-coated high strength stainless steel flats and alumina ball bearings were used as model wear couples. Dry sliding wear tests were performed on various CrN architectures at cold (-20 °C) and warm (30 °C) surface temperatures in low dew point air (<-20 °C). The repeatability of the testing approach was established by replicating environmental test conditions across multiple tests on the same flat sample. Wear scars were analyzed using laser scanning confocal microscopy and optical microscopy. Comparisons of coefficient of friction behavior as a function of sliding distance revealed that specific protective coating architectures respond differently to Arctic conditions.

MC-ThP-10 Validity of the 10% Rule of Thumb in Coatings Nanoindentation*, **Esteban Broitman [ebroitm@hotmail.com]**,* EDB Engineering Consulting, France

When an indenter penetrates the surface of a film deposited onto a substrate, the mechanical response of the coating will be influenced by the mechanical properties of the substrate, according to its penetration depth h and the film thickness t. As the depth of penetration h increases, more of the mechanical contribution will come from the substrate.

The first who tried to separate the contribution of the substrate from the total measured hardness at the microscale was Bückle, who suggested a 10% rule of thumb: to indent no more than 1/10 of the film thickness to avoid the influence from the substrate. The rule has been adopted later by many researchers for nanoindentation experiments and extended also as valid for the elastic modulus. However, there are many experimental studies and numerical simulations showing that this rule is too strict for a hard coating on a very soft substrate and too loose for a soft coating on a hard substrate [1].

In this presentation, we will review the issue, and will discuss all factors that affect the maximum penetration depth for independent coating measurements. We will also present a simple experimental methodology that, in most of cases, gives the correct values for hardness and elastic modulus, independently of the coating/substrate system.

[1] E. Broitman, Indentation Hardness Measurements at Macro-, Micro-, and Nanoscale: A Critical Overview. Tribol. Lett. 65 (2017) 23.

MC-ThP-11 Enhancing the High-cycle Fatigue Strength of Ti-Al-N Coated Ti-6Al-4V by Residual Stress Design*, **Arno Gitschthaler [arno.gitschthaler@tuwien.ac.at]**, Rainer Hahn, Lukas Zauner, Tomasz Wojcik,* TU Wien, Institute of Materials Science and Technology, Austria*; Florian Fahrnberger, Herbert Hutter,* TU Wien, Austria*; Anton Davydok, Christina Krywka,* Helmholtz Zentrum Hereon, Institute of Materials Physics, Germany*; Jürgen Ramm, Anders Eriksson,* Oerlikon Balzers, Oerlikon Surface Solution AG, Liechtenstein*; Szilard Kolozsvari, Peter Polcik,* Plansee Composite Materials, Germany*; Helmut Riedl,* TU Wien, Institute of Materials Science and Technology, Austria

Physical vapor deposited ceramic coatings are widely utilized to protect components operating in harsh environments, yet their influence on the high-cycle fatigue behavior of metallic substrates remains a subject of debate. In this study, the residual stress-dependent effect of arc evaporated TiAlN-based thin films on the fatigue life of Ti-6Al-4V was investigated. By employing various stress-modifying strategies — *(i)* including a substrate bias variation, *(ii)* a tantalum-based alloying approach, *(iii)* and a tailored interlayer design — we systematically modified the residual stress profiles within the coating and interface near substrate region. High-cycle fatigue tests, performed in a single cantilever configuration using a dynamic mechanical analyzer, revealed that a sufficiently pronounced residual compressive stress state within the TiAlN layer is critical to preventing premature failure. Once the residual compressive stress field effectively shifts fatigue crack nucleation into the bulk material, an improvement in the high-cycle fatigue limitof over 50% was achieved compared to the uncoated titanium alloy (from 420 MPa to 628 MPa at 10^7 cycles).

To clarify the underlying mechanisms, a combination of high-resolution characterization techniques — namely high-resolution transmission electron microscopy (HR-TEM), transmission electron backscatter diffraction (t-EBSD), time-of-flight secondary ion mass spectrometry (ToF-SIMS), transmission X-ray nanodiffraction (CSnanoXRD), and micro-mechanical synchrotron-based experiments at DESY’s PETRA-III — was employed. These experimental insights were integrated into a simple linear-elastic stress-failure model, providing an analytical framework to support the experimentally observed fatigue enhancements. The study not only resolves previous contradictory findings regarding the detrimental versus beneficial effects of hard ceramic coatings on fatigue performance but also establishes clear criteria for optimizing coating design. In particular, our results demonstrate that an optimized residual stress distribution is key to deploying the full potential of HCF-resistant TiAlN-based coatings. Adjusting process parameters and designing the interlayer helps maximize TiAlN coatings' effectiveness for extending the lifespan of Ti-6Al-4V parts.

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