MM 8: Topical Session: Nanomechanics of nanostructured materials and systems II - Thin films

Time: Monday 11:45–13:00 Location: BAR 205

Topical Talk MM 8.1 Mon 11:45 BAR 205

The Fatigue and Time-Dependent Properties of Freestanding and Supported Thin Gold Films Studied by Bulge Tests — •Benoit Merle and Mathias Göken — Department of Materials Science and Engineering, Institute I, Friedrich-Alexander-University Erlangen-Nürnberg, Germany

The bulge test is a method of choice for investigating the mechanical properties of thin films. Its scope was extended to the study of fatigue and time-dependent properties of freestanding and SiNx supported 100 - 400 nm gold films. Fatigue testing is performed by cycling the pressure under the membrane up to 10^5 times, while the stress and strain in the membrane are continuously measured. Freestanding films experienced a strong ratcheting leading to failure after a few 10^4 cycles. Observations of the surface showed a sliding of individual grains below the level of the original surface. This grain boundary sliding was obviously eased by the columnar microstructure of the samples. SiNx supported films did neither experience failure nor such strong effects. Only a few abnormally large grains showed extrusions after completion of the fatigue tests. Cyclic creep having been observed for both kinds of samples, creep tests were performed on them. They evidenced widespread grain boundary sliding across the freestanding gold membranes, while this mechanism was prevented by the good adhesion of supported films to their substrate. Strain-rate jump tests showed that this resulted into freestanding gold films having a strain-rate sensitivity 5 times higher than their counterparts bonded to a SiNx substrate.

MM 8.2 Mon 12:15 BAR 205

Fracture Behavior of Freestanding Thin Metal Films Characterized by Bulge Testing — •Eva Preiss, Benoit Merle, and Mathias Göken — Department of Materials Science and Engineering, Institute I, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany

A bulge test setup was used to perform mechanical tests on rectangular membranes with thicknesses ranging from below 100 nm to 400 nm. From conventional bulge tests, stress-strain curves can be calculated and parameters such as residual stress and plane-strain modulus can be determined. Alternatively, the used setup can be inserted into an atomic force microscope (AFM). During in-situ bulge testing in the AFM the surface of the deforming membrane can be imaged.

In order to determine the fracture toughness of thin films, narrow slits of 10 um length were milled into the center of the membranes by focused ion beam (FIB). Subsequently, the membranes were loaded until rupture. The fracture toughness obtained for freestanding and supported gold films is far below the fracture toughness reported for bulk gold. By in-situ testing in the AFM out-of-plane motion of individual columnar grains could be revealed as active deformation mechanism in freestanding films.

MM 8.3 Mon 12:30 BAR 205

Mechanical properties of reactively sputtered ceramic single and multilayer thin film structures for dental implants — •Daniel Muff and Ralph Spolenak — ETH Zurich, Laboratory for Nanometallurgy, Switzerland

Due to their inherent dark grey color, titanium dental implant screws can cause undesired darkening of the peri-implant mucosa [1]. Ceramic single and multilayer thin film structures have been developed to increase their reflectance based on interference phenomena.

Besides the esthetic function, the mechanical integrity of the coatings is crucial. As implants bend during chewing motions, coatings have to withstand compressive and, more critically, tensile strains. Therefore, in-situ tensile testing of the ceramic films on polyimide and titanium substrates has been carried out in optical and scanning electron microscopes in order to determine their fracture and delamination behavior.

It was found that the strain at onset of fragmentation decreases with increasing film thickness or number of layers. The crack distance saturates at around 10 times the film thickness and is slightly smaller for coatings on Ti than on polyimide which can be explained by the mismatch of the elastic constants of film and substrate [2]. While buckle formation was observed for thin films, thicker films showed severe delamination.

References: [1] SE Park, JD Da Silva, H-P Weber, S Ishikawa-Nagai (2007) Clinical Oral Implants Research 18: 569. [2] ZC Xia, JW Hutchinson (2000) Journal of the Mechanics and Physics of Solids 48: 1107.

MM 8.4 Mon 12:45 BAR 205

Influence of the Film Thickness on Fragmentation, Adhesive Failure and Contact Damage of Diamond-Like Carbon (DLC) Coated Titanium Substrates — •Daniel Bernoulli[1], Andi Wyss[1], Kathrin Häfliger[1], Kerstin Thorwarth[2], Götz Thorwarth[3], Roland Hauert[2], and Ralph Spolenak[1] — [1]ETH Zurich - Laboratory for Nanometallurgy, Department of Materials, Zurich, Switzerland — [2]EMPA, Swiss Federal Laboratories for Materials Science and Research, Dübendorf, Switzerland — [3]DePuy Synthes, Solothurn, Switzerland

Diamond-like carbon (DLC) coated friction pairs are well-known for their long durability and outstanding tribological behavior. However, wear and loose particles trapped between the friction pairs can lead to the appearance of high pressure on the DLC coating and may result in contact damage, fragmentation and adhesive failure. The influence of the DLC film thickness on these three effects is presented in this talk. The contact damage upon indentation was analyzed by finite element analysis and experimental studies. For thicker films circumferential and horizontal cracks are present in the DLC while for thin DLC films pronounced plastic deformation of the substrate occurs. The fragmentation analysis reveals that a very high DLC fracture strength can be achieved by keeping the DLC film thickness <1 μm and adhesive failure correlates with film thickness and the applied strain. For all three cases an optimal DLC film thickness is presented.