MM 53: Topical Session: Fundamentals of Fracture - Novel Experimental Techniques II

Time: Thursday 11:45–13:00 Location: H4

MM 53.1 Thu 11:45 H4

Investigation of the fracture behavior of Tungsten at the micro scale — •Nicola Julia Schmitt[1], Christoph Bohnert[1,2], Christoph Eberl[1], Oliver Kraft[1], and Sabine Maria Weygand[2] — [1]Institute for Applied Materials, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen (Germany) — [2]Department of Mechanical Engineering and Mechatronics, Karlsruhe University of Applied Sciences, 76133 Karlsruhe (Germany)

Tungsten promises great potential as structural material in power generation due to its high melting point. One challenge however, is to deal with its ductile-to-brittle transition far above room temperature which limits its application. Studies at the macro scale have shown that microstructural characteristics have a big influence on the fracture toughness of tungsten. Moreover, it was shown that tungsten can be fairly ductile at small scale for sample sizes below 100 μm. To deepen the insight into the underlying fracture mechanisms, tests are carried out at the micro scale, which are supported by finite element simulations.

To investigate the influence of the crystal orientation and grain boundaries two different types of beams were tested, namely single crystal microbeams with different orientations and bi-crystalline microbeams with varied grain boundary orientations. The micro bending beams with 30 μm in width and 200 μm in length have been fabricated and notched by a combined method of micro-electro-discharging machining and focused ion beam. Fracture experiments are conducted by using a nanoindentation system. First results indicate that fracture is rather brittle when the notch is aligned an expected cleavage plane.

MM 53.2 Thu 12:00 H4

Cracking in 'nanocomposite' CrAlN/Si3N4 hard coatings — Shiyu Liu[1], Jeff Wheeler[2], Philip R. Howie[1], Xiangting Zeng[3], Johann Michler[2], and •William J. Clegg[1] — [1]Gordon Laboratory, Department of Materials Science & Metallurgy, Pembroke St, Cambridge CB2 3QZ, UK — [2]EMPA, Feuerwekerstrasse 39, CH-3062 Thun, CH — [3]Singapore Institute of Manufacturing Technology, 71 Nanyang Drive, Singapore 638075

Recent work has shown that the flow behaviour of hard coatings of a very fine-grained CrAlN/Si3N4 is similar to that predicted by expanding cavity type models. However, preliminary observations suggest that the cracking behaviour of these materials is somewhat different to that observed in more conventional CrAlN hard coatings. In this paper, a double cantilever beam method has been developed to study the nature of crack growth in hard coatings. The test method is first described, including a way of correcting for frictional effects between the punch and the sample. The measured values of the crack resistance of SiC and GaAs are compared with those obtained at larger scales. The method is then used to measure the resistance to cracking in different hard CrAlN-based coatings and to study how a crack grows through the coating and the influence of the coating microstructure.

MM 53.3 Thu 12:15 H4

Bulge testing as a tool for investigating the fracture properties of thin films - Application to silicon nitride and gold membranes — •Benoit Merle and Mathias Göken — Department of Materials Science and Engineering, Institute I, University Erlangen-Nürnberg, Germany

The bulge test was developed into a valuable tool for investigating the fracture mechanism of very thin films (30 - 300 nm). The improved sample preparation includes milling a crack-like slit in the center of the membrane, using a Focused Ion Beam. The samples are then pressurized in the bulge test until failure occurs. Optionally, the experimental setup is inserted into an AFM, which allows in-situ imaging of the extension of the crack. The presentation will show applications on thin amorphous silicon nitride and nanocrystalline gold films. As a brittle material, silicon nitride is well suited for the quantitative measurement of the fracture toughness KIC. The bulge test results show that the fracture toughness does not depend on the thickness of the SiNx film, although its state changes from plane-strain to plane-stress. Since gold is a more ductile material, the focus was laid on the in-situ AFM observations of the crack propagation. Grain boundary sliding was observed to occur in these thin films, which probably accounts for the low toughness found for gold thin films.

MM 53.4 Thu 12:30 H4

The Effect of Prior Heat Treatment on the Fracture Energy of Metal Fibre Reinforced Ceramic Composites (MFCs) — •Su Ki Lam, Louise Gale, and Bill Clyne — Department of Materials, Pembroke Street, Cambridge CB2 3QZ UK

This work concerns the fracture energy of alumina matrix composites with (~15vol%) steel fibres. A recent model [1] gives the work of fracture from pull-out and/or plastic deformation of fibres bridging the crack plane. The present work concerns exposure to high temperature (~1,000C). The standard fibre is 304, with strength and ductility that confer toughness on the composite, mainly from fibre plasticity. However, this steel has poor oxidation resistance. Since the matrix offers little environmental protection, this oxidation can be extensive, reducing ductility and creating defects within the composite. The toughness can thus fall sharply after heat treatment. The study also covers another steel (310) with superior oxidation resistance. Fibres of 310 exhibit lower strength and ductility than 304 (as-received), but are less prone to oxidation-induced degradation of these properties. The fracture energy after heat treatment can thus be higher with 310 fibre, and fracture energy values are consistent with model predictions and experimental single fibre tensile data. Results are also presented concerning oxidation and microstructural changes. [1] S.R. Pemberton, E.K. Oberg, J. Dean, D. Tsarouchas, A.E. Markaki, L. Marston & T.W. Clyne, The fracture energy of metal fibre reinforced ceramic composites (MFCs), Composites Science and Technology, vol.71 (2011) p.266-275.

MM 53.5 Thu 12:45 H4

Plasticity and fracture in drying colloidal films — •Lucas Goehring[1], William J. Clegg[2], and Alexander F. Routh[3,4] — [1]MPI Dynamics and Self-Organization, Göttingen, Germany — [2]Department of Materials Science and Metallurgy, University of Cambridge, UK — [3]Department of Chemical Engineering and Biotechnology, University of Cambridge, UK — [4]BP Institute for Multiphase Flow, University of Cambridge, UK

Cracks in drying colloidal dispersions are typically modelled by elastic fracture mechanics, which assumes that all strains are linear, elastic, and reversible. We tested this assumption in films of a hard latex, by intermittently blocking evaporation over a drying film, thereby relieving the film stress. Here we show that although the deformation around a crack tip has some features of brittle fracture, only 20-30% of the crack opening is relieved when it is unloaded. Atomic force micrographs of crack tips also show evidence of plastic deformation, such as micro-cracks and particle rearrangement. Finally, we present a simple scaling argument showing that the yield stress of a drying colloidal film is generally comparable to its maximum capillary pressure, and thus that the plastic strain around a crack will normally be significant. This also suggests that a film's fracture toughness may be increased by decreasing the inter-particle adhesion.