MM 12: Topical Session (Symposium MM): Fundamentals of Fracture

Joint session of Mechanical Properties at Small Scales and Fundamentals of Fracture: Small Scale Fracture Experiments

Fundamentals of Fracture organized by Erik Bitzek (U Erlangen-Nürnberg, Germnany), Sandra Korte-Kerzel (RWTH Aachen University, Germany) and Peter Gumbsch (Fraunhofer Institute for Mechanics of Materials, Freiburg, Germany)

Time: Monday 15:45–17:15 Location: TC 006

Topical Talk MM 12.1 Mon 15:45 TC 006

Microscale Fracture Testing: State of the Art and Future Challenges — •David Armstrong — University of Oxford, Oxford, UK

Over the last 15 years there has been a large increase in the use of microscale fracture tests. This is linked to the increase in availability of focused ion beam systems allowing the manufacture of increasingly complex test geometries and improvements in nanoindetation equipment allowing the testing of smaller and more complex structures. In addition the development of high temperature nanoindentation systems allows for microscale studies of the effects of temperature on fracture behaviour.

This paper will give an overview of the current state of the art in the area of microscale fracture. Specific examples that will be used to demonstrate this will include microscale measurements brittle to ductile transition in tungsten alloys and a comparison of micro and microscale fracture of oxidised grain boundaries in nickel alloys.

Finally some future directions will be suggested for research and to stimulate discussion.

MM 12.2 Mon 16:15 TC 006

Damage in DP Steel - statistical in-situ analysis of brittle and ductile mechanisms prior to the onset of fracture — •Carl F. Kusche[1], Martina Freund[1], Tom Reclik[1], Ulrich Kerzel[2], Talal Al-Samman[1], and Sandra Korte-Kerzel[1] — [1]Institut für Metallkunde und Metallphysik, RWTH Aachen, Germany — [2]Lehrstuhl für Operations Research, RWTH Aachen, Germany

For the last years, analysing deformation damage in dual-phase steels has been a well-discussed topic; this is largely due to the ongoing rise in demand for high-strength steels with good ductility, allowing for a further optimization in weight reduction.

To reveal the micromechanical mechanisms of damage, the currently undergone methods of post-mortem analysis as well as in-situ methods deliver an incomplete picture; the first being unable to deliver data for the evolution of damage while classically, in-situ methods being spatially limited to the observation of few damage events. The novel approach in this work combines in-situ observation with an automated recognition and classification of micromechanical damage mechanisms. An algorithm based on machine learning is developed to achieve this methodical expansion, allowing the analysis of large deformed areas while at the same time maintaining spatial resolution. The in-situ experiment is enhanced by the possibility of generating statistically relevant data characterizing the mechanisms of fracture in brittle phases and ductile void formation on the microscale. Thus, exposing the evolution of predominant damage mechanisms during deformation yields a holistic approach to deformation damage.

MM 12.3 Mon 16:30 TC 006

The brittle-ductile transition of tungsten single crystals at the micro-scale — •Johannes Ast, Jakob Schwiedrzik, Juri Wehrs, Johann Michler, and Xavier Maeder — Empa, Swiss Federal Laboratories for Materials Science and Technology, Feuerwerkerstrasse 39, 3602 Thun, Switzerland

Notched micro-cantilevers were prepared by focused ion beam (FIB) milling in a tungsten single crystal. This material has nearly perfect elastic isotropy, a limited amount of activated slip systems and detailed knowledge of the macroscopic fracture behaviour is available. The cantilevers have dimensions of 25 μm in length, 5-7 μm in thickness and crack length to thickness ratios a/w of ca. 0.4. Loading rate and temperature are known to influence the fracture behaviour decisively in bcc metals. Therefore displacement-controlled fracture tests were performed inside a scanning electron microscope in the temperature range between -90°C and 500°C. Applying the J-Integral technique to plot continuous crack resistance curves, the fracture toughness and brittle-to-ductile transition (BDT) temperatures, which depend on the applied loading rate, were determined. This allows a thorough investigation of the activation energy of the BDT at the micro-scale.

MM 12.4 Mon 16:45 TC 006

Influence of pre-deformation on the microscale fracture toughness of bcc-materials — •Stefan Gabel, Merle Benoit, and Mathias Göken — Dapartment of Materials Science and Engineering Institute I - General Materials Properties, Erlangen, Germany

The ductility of bcc-Materials is often insufficient for structural applications at low temperatures. The transition to brittle fracture below a critical temperature is likely caused by two possible mechanisms. Either the dislocation mobility is limited or the nucleation sources cannot be activated. In order to find out, semibrittle materials with dislocation gradients were investigated with microcantilevers.

In order to apply achieve a specific initial dislocation density, indentations were made on a sample surface. The resulting plastic strain field in the material was analyzed by FEM in order to identify areas with homogeneous deformation for fracture tests. The cantilevers for the fracture tests had a diameter of 3000 nm and were milled with a FIB. Testing was achieved by two different approaches. On the one hand an in situ setup with a micromanipulator was used to directly observe crack growth and tip blunting. On the other hand an ex-situ nanoindenter setup was used, which offered better displacement resolution and a larger load range.

The measurements show the dependence of the transition in the fracture behavior on the availability and activity of dislocations sources. Nevertheless the fracture toughness is also dependent on the mobility of dislocations at different temperatures.

MM 12.5 Mon 17:00 TC 006

In Situ TEM and SEM Fracture Experiments at RT — •Inas Issa and Daniel Kiener — Department Materials Physics, Montanuniversitat Leoben, Austria

Among high strength and elastic limit that materials gain when decreasing their volumes to the sub-micron range, they exhibit large plastic deformation under high load. Mechanisms proposed are mainly size, among other parameters, dependent. Fewer studies are dedicated on the investigation of the *intrinsic* size effect on the strengthening of materials, i.e. fracture experiments at RT in the nanoscale. A good knowledge of the critical size for materials strengthening and for BDT of brittle materials, allows better design guideline of more fracture resistant, tough materials and avoid brittle failure of semiconductors used in many advanced microelectronic devices. We present in situ TEM fracture experiments at RT on metallic and semiconductors single crystals nanobending beams of thickness ranging from [70-400] nm. Dislocations activities and characters at the notche zone are investigated. Size effect on notch blunting and increase of fracture toughness is observed. Notches are introduced in TEM and others using Fib. Thus, a comparative study on the notches size effect on fracture toughness measurements is performed. In situ SEM fracture tests on similar but larger metallic samples are performed and on ultrafine grains ones. Thus, the influence of interfaces on the crack propagations is also studied.