MM 22: Mechanical properties I - Plastic deformation & fracture

Time: Tuesday 10:15–11:45 Location: IFW B

MM 22.1 Tue 10:15 IFW B

Ductile-to-brittle transition in metallic glasses under cryogenic cooling — •Minqiang Jiang — State Key Laboratory of Nonlinear Mechanics, Institute of Mechanics, Chinese Academy of Sciences, Beijing 100190, PR China — Institute of Materials Physics, Westfälische Wilhelms-Universität Münster, Münster 48149, Germany

At temperatures well below the glass transition temperature, the failure of metallic glasses is generally induced by shear-banding that is a result of the self-organized shear transformation zones (STZs). Here, we demonstrate that upon cooling down to liquid-helium temperature (4.2 K), a Zr-based metallic glass can fail via cavitation rather than by shear-banding due to the intervention of a ductile-to-brittle transition. This is supported by the breakdown of low-temperature strengthening of materials, as well as the change of fracture modes from shear to tension and fracture morphologies from vein-pattern to fine dimple or nanoscale periodic corrugation. We propose that a temperature-dependent STZ-dilatation, defined as the ratio of mobile free-volume to STZ-volume, controls the ductile-to-brittle transition, and across the transition point the STZ-type rearrangements of atomic-cluster will convert into the cavitation-dominated operations, i.e., tension transformation zones. Our findings shed new insight into fracture strength and energy dissipation mechanism in amorphous alloys, particularly at very low temperatures.

MM 22.2 Tue 10:30 IFW B

Microstructural influences on inhomogeneous plastic flow in AA2198 — •Henry Ovri and Erica Lilleodden — Helmholtz Zentrum Geesthacht, Institute of Materials Research, Materials Mechanics, Geesthacht, Germany

Inhomogeneous plastic flow has been reported in several Al alloys and is known to severely limit the formability of sheet metals and promote the formation of undesirable striations on the surface of the deforming part. Understanding the micromechanisms responsible for the occurrence of these plastic instabilities is pivotal to the design of alloys and process routes that mitigate the effect. Although it is widely accepted that the phenomenon is associated with dynamic strain aging (DSA) and negative stain rate sensitivity (NSRS), the effect of precipitation in retarding or enhancing the instabilities is still not clear. In this work, the effect of precipitation on inhomogeneous plastic flow in an Al-Li based alloy (AA2198) is investigated by using nanoindentation, atom probe microscopy and in situ TEM straining methods. The results are discussed on the basis of the observed interactions between matrix dislocations and coherent ordered δ' (Al_3Li) precipitates, residual matrix solute content and dislocation-particle interaction theories.

MM 22.3 Tue 10:45 IFW B

Tuning tensile ductility in composite structured Ti-based alloys — •Ilya Okulov[1,2], Uta Kühn[1], Jens Freudenberger[1,3], Werner Skrotzki[4], and Jürgen Eckert[1,2] — [1]IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany — [2]Technische Universität Dresden, Institut für Werkstoffwissenschaft, D-01062 Dresden, Germany — [3]Technische Universität Bergakademie Freiberg, Institut für Werkstoffwissenschaft, Gustav-Zeuner- Str. 5, D-09599 Freiberg, Germany — [4]Technische Universität Dresden, Institut für Strukturphysik, D-01062 Dresden, Germany

Due to a well-balanced structure, Ti-based ultrafine-dendrite composites exhibit high strength and compressive plasticity already in the as-cast state. They consist of a β-Ti phase surrounded by ultrafine structured intermetallics: the β-Ti phase is ductile and tough one, while the brittle intermetallics effectively strengthen the alloys. The most of Ti-based ultrafine-dendrite composites are brittle in tensile loading. Recently, it was reported that the control of precipitates in the Ti-Nb-Cu-Ni-Al system can significantly enhance tensile ductility and maintaining high yield strength [1]. The approach was successfully applied to several Ti-based systems. And new composite structured alloys with high strength and tensile ductility were developed. For example, Ti68.8V13.6Cu6Ni5.1Al6.5 exhibits the ultimate strength of about 1250 MPa and the tensile ductility of about 4.5%.

1. Okulov et al. - Materials Science and Engineering C, 33 (2013) 4795-4801

MM 22.4 Tue 11:00 IFW B

***Ab-initio* modelling of mode I cleavage** — •Beatrix A. M. Elsner and Stefan Müller — Hamburg University of Technology, Institute of Advanced Ceramics, Denickestr. 15, D-21073 HH

In this contribution we focus on the atomistic modelling of fracture, employing density functional theory to investigate the response of Cu and TiO_2 to mode I loading. As long as structural relaxations are omitted, the universal binding energy relation [1] may be applied to obtain the theoretical strength. However, relaxations can significantly affect the cleavage energy, and the stresses due to rigid displacement can only be considered an upper limit. If atomic relaxations are allowed, cleavage is treated as an energy minimization problem, and rupture will occur at the critical displacement l_c for which the Griffith criterion is fulfilled: $E_{\mathrm{strain}}(l_c) = E_{\mathrm{cleavage}}(l_c)$. As the strain energy depends on the system dimension perpendicular to the cleavage plane, the critical displacement is proportional to the square root of this system dimension. A consequence of this size effect are unphysical results in the limit of large system dimensions. We have used the nudged elastic band method (NEB) to study the transition from strain to cleavage, and we find that the energy barriers involved in the transition increase with increasing system size. This opposes the above-mentioned size effect and may limit the critical displacement. Further, our calculations suggest that prior to surface separation, the strain will localize close to the cleavage surfaces.
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[1] J. H. Rose, J. R. Smith, J. Ferrante, *Phys. Rev. B* **28**, 1835 (1983).

MM 22.5 Tue 11:15 IFW B

Residual stresses and internal architectures of AlSi-alloys for cast engine components — Michael Schöbel[1], Georg Baumgartner[2], and •Stefan Gerth[3] — [1]Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II), TU Munich, Germany — [2]Umformtechnik und Gießereiwesen, TU Munich, Germany — [3]Entwicklungszentrum für Röntgentechnik, Fraunhofer Institut Fürth, Germany

The increasing demand on weight and efficiency of modern combustion engines requires light alloys with improved high temperature strength and creep resistance. New cast AlSi alloys are developed to increase wear resistance and long term stability of engine components. In such materials with a composite-like micro structure high stress gradients lead to crack formation and damage under operation conditions.

Neutron diffraction is applied for micro stress analysis after casing as well as during tensile testing between the α-Al and Si phase. Complementary high resolution synchrotron tomography allowed 3D imaging of damage mechanisms and crack propagation. Both methods were combined to develop a micro-mechanical model for stress simulation and to validate its reliability for engineering AlSi alloys under reproducible boundary conditions.

MM 22.6 Tue 11:30 IFW B

In-situ Fatigue, Fracture and Dynamic Mechanical testing in the SEM — •Douglas Stauffer, Sanjit Bhowmick, Ryan Major, S.A. Syed Asif, and Oden Warren — Hysitron, Inc. 9625 West 76th St. Minneapolis MN

Rapid expansion of in situ nanomechanical testing gives researchers a means of testing and exploring fundamental deformation mechanisms. Here, new instrumentation involving novel control algorithms to control system quality factor is described, which allows the use of dynamic measurements without undesirable system oscillation. These dynamic measurements can then be used to explore frequency dependency, strain rate, fatigue, and crack propagation in a variety of materials. Here, frequency dependent effects are used to explore the effect of electron beam induced viscoplasticity in micron sized silica spheres. When tested without the presence of an electron beam, these spheres fracture at strains of less than 2%. However when irradiated at 20keV and 30pA in an SEM, the spheres can be deformed to strains of more than 50% under certain conditions. Rapid loading and high frequencies, correlated with high strain rates, result in fracture at strains of approximately 10% under e-beam irradiation. This is in contrast to slow loading and low frequency load controlled dynamic loading, where strains as large as 60% without fracture have been achieved.