MM 38: Liquid and Amorphous Metals

Time: Wednesday 15:00–17:00 Location: H 1029

MM 38.1 Wed 15:00 H 1029

Probing Shear-Band Initiation in Metallic Glasses — •David Klaumünzer, Robert Maass, Peter Thurnheer, and Jörg F. Löffler — Laboratory of Metal Physics and Technology, ETH Zurich, Wolfgang-Pauli-Strasse 10, 8093 Zurich, Switzerland

At low homologous temperatures, metallic glasses are known to deform inhomogeneously by the formation of nanometer-sized shear bands. Typically, the operation of these bands is intermittent as reflected in serrated flow curves. This can be best understood in the context of stick-slip in which extended periods of arrest are followed by rapid slip events. The strong localisation of flow in space coupled with the fast operation of shear bands poses severe experimental challenges. We have approached this problem by using in-situ acoustic emission monitoring during compression testing of a Zr-based metallic glass. With this method, the mechanism of shear-band initiation prior to each slip event can be resolved. By drawing an analogy to the intermittent flow behaviour of granular media, we attribute the acoustic emission signal to a local volume expansion within a shear band. A quantitative analysis reveals volume changes for shear band initiation of a few percent only, in agreement with the excess free volume typical of the supercooled liquid regime.

[1] D. Klaumünzer et al., Physical Review Letters 107, 185502 (2011).

MM 38.2 Wed 15:15 H 1029

Size-dependent embrittlement in Zr-based bulk metallic glasses and its correlation to shear band velocities — •Peter Thurnheer, David Klaumünzer, Robert Maass, and Jörg Friedrich Löffler — Laboratory of Metal Physics and Technology, Department of Materials, ETH Zürich, 8093 Zürich, Switzerland

Despite extensive research during the last decades, plastic flow in metallic glasses remains a topic of intense debate. Since all metallic glasses are brittle in tension ($\epsilon_p < 0.5\%$), experimental focus lies on compression testing, where for some alloys, such as $Zr_{52.5}Cu_{17.9}Ni_{14.6}Al_{10}Ti_5$ (Vit105), several percent apparent plasticity can be observed. However, the amount of total plastic strain generated is found to depend highly on sample geometry, temperature and stiffness of both testing equipment and sample. Based on recent research that showed that one serration in the serrated flow regime of the stress-strain curve can be linked to the initiation, propagation and arrest of a single shear band, this work investigates the embrittlement of metallic glasses due to increasing specimen size, by analyzing the dynamics of single serrations with high temporal resolution. Samples with diameters ranging from 2 to 5 mm were tested. Similar to the case of metallic glass embrittlement as a function of increasing temperature, it was found that the total plastic strain to failure decreases with increasing sample diameter and that this decrease correlates with an increase of shear-band velocity during individual serrations.

MM 38.3 Wed 15:30 H 1029

Strain localization in amorphous Cu-Zr nanowires: Molecular dynamics simulations on the influence of size, surface relaxation state and temperature — •Yvonne Ritter and Karsten Albe — Institut für Materialwissenschaft, Technische Universität Darmstadt, Petersenstr. 32, 64287

Plastic deformation in bulk metallic glasses occurs at room temperature highly localized in narrow shear bands. Recent experiments, however, suggest a transition in deformation mode, from shear banding to a more homogeneous plastic deformation, if sample dimensions reach the nanometer regime. Despite the growing number of reports on size-dependent plasticity, doubts about the intrinsic nature of this size effect persist. When it comes to mechanical testing of nanoscale specimen, experimental artifacts can change the operating deformation mechanism.

In this study, cylindrical amorphous nanowires with diameters of 5-20 nm are studied by molecular dynamics simulations under tensile load. Two different amorphous alloys, a $Cu_{64}Zr_{36}$ and a $Cu_{36}Zr_{64}$ glass, are compared. By varying the surface relaxation state, temperature and sample diameter we find from the analysis of a statistically relevant number of samples no evidence for an intrinsic size-dependent transition in deformation mode. In both alloys, the occurrence of shear bands, neck formation or homogeneous flow is solely determined by the nucleation and coalescence of shear transformation zones exhibiting a size-independent activation free energy.

MM 38.4 Wed 15:45 H 1029

A model for superplastic deformation of metallic glasses — •Jonas Bünz[1], Gerhard Wilde[1], and K. Anantha Padmanabhan[2] — [1]Institut für Materialphysik, WWU Münster — [2]University of Hyderabad

The deformation behaviour of bulk metallic glasses is different from that of crystalline materials in that no restriction is placed on it that the displacement vector should be relared to the lattice parameter. Applied stresses get localized, lead to shear band formation and cause catastrophic failure after little or no plastic strain. In the supercooled liquid region, however, bulk metallic glasses can experience large strains; even superplasticity. We present a model for superplastic deformation of bulk metallic glasses, subjected to deformation in the supercooled liquid region. The model is based on the formation of shear transformation zones on a microscopic scale and the consequential development of mesoscopic glide planes of several nm. The model has been validated using experimental stress / strain rate data petaining to eight different glassy systems and is able to estimate the experimental strain rates within a factor of two. Based on this analysis the activation energy for rate controlling deformation and the threshold stress needed for the onset of interfacial sliding can be determined. Comparison with results obtained through other measurements reveals that the deductions based on the model are physically very meaningful.

MM 38.5 Wed 16:00 H 1029

Investigation of solidification dynamics of undercooled melts of Cu-Zr alloys — •Raphael Kobold[1], Dieter Herlach[1,2], and Ulrich Köhler[2] — [1]Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt, 51170 Köln, Germany — [2]Institut für Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

In contrast to experiments with most undercooled binary alloys the velocity of dendritic growth of a $Cu_{50}Zr_{50}$ alloy does not increase monotonically with undercooling but passes through a maximum and then decreases. To study this behaviour we investigate Cu-Zr alloys with Zirconium concentrations ranging from 44 to 54 at.% including eutectic and intermetallic phases. We use electrostatic levitation technique to melt and undercool samples with a diameter of 2-3mm under ultra-high-vacuum. Containerless processing is an effective tool for undercooling metallic melts far below their equilibrium melting temperatures since heterogeneous nucleation on container walls is completely avoided. During crystallisation of the undercooled melt the heat of crystallisation is released. The rapid increase of the temperature at the solid-liquid interface makes the solidification front visible. The velocities of the solidification front are measured by using a high-speed camera with a maximum frame rate of 50 000 pictures per second. Furthermore, experiments for phase selection during rapid solidification of the undercooled Cu-Zr melts were performed at DESY Hamburg.

MM 38.6 Wed 16:15 H 1029

A study of phase separation in Zr-Gd-Co-Al metallic glasses — •Junhee Han[1,2], Norbert Mattern[1], and Jürgen Eckert[1,2] — [1]IFW-Dresden, Institute for Complex Materials, Dresden, Germany — [2]TU Dresden, Institute of Materials Science, Dresden, Germany

The Zr-Co-Al and Gd-Co-Al ternary alloys are well known bulk metallic glass-former that could be cast into cylindrical rods with diameters up to 18 mm and 5 mm, respectively [1-2]. Since the binary Zr-Gd system has a miscibility gap in the solid state, i.e. Zr and Gd tend to separate from each other, the quaternary Zr-Gd-Co-Al system is a promising candidate to form phase separated glass-glass composites. In this work, Zr56-xGdxCo28Al16 (x = 2 - 20 at.%) melt-spun ribbons are characterized. The structure are further studied by In-situ small-angle and wide-angle X-ray scattering (SAXS/WAXS) at elevated temperature. Heat treated ribbons for x = 5 and 10 are additionally investigated by atom probe tomography. For ribbons with relatively low Gd content (x = 10 at. %), no indication for phase separation is found by general analysis such as SEM, XRD and DSC. In-situ SAXS/WAXS at elevated temperature gives evidence for formation of heterogeneity prior to crystallization. Atom probe tomography measurement also illustrates that the ribbons x = 5 and 10 undergo phase separation resulting in Gd-rich nano-scale precipitates prior to crystallization.

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[1] T. Wada et al., J. Mater. Res, 24(2009)8
[2] D. Chen et al., Mater. Sci. Eng. A, 457(2007)226

MM 38.7 Wed 16:30 H 1029

Fraction of un-displaced atoms, structure conserving correlations, and temporal decay of structure fluctuations in simulated Ni0.5Zr0.5 melt — •Helmar Teichler — Inst. f. Materialphysik, Univ. Göttingen, Göttingen, Germany

The highly elaborated mode coupling theory provides a powerful tool to describe the temporal decay of fluctuations in melts. Notwithstanding this, there remains the question for the atomistic process behind the decay. To approach this problem, we analyzed simulation data of a Ni0.5Zr0.5 model close to its glass temperature at the accessible cooling rates. Recurring to our recent approach (H. Teichler, PRL, 107,067801 (2011)) we used as main tool the time evolution of the fraction of undisplaced particles (FUDP). The analysis shows that the alpha decay reflects the ultimate decrease of the FUDP. It irrefutably proves that the structural decay is due to temporal accumulation of incoherent short-ranged displacement events, where the stretched exponential behavior reflects structure conserving correlation in the accumulation process. In the contribution we present, in particular, a concise iteration procedure that describes the fluctuation decay over about eight decades from atomic vibrations to the beta and the alpha region.

MM 38.8 Wed 16:45 H 1029

Ultrafast Heating of Metallic Glasses using a Multistep Rapid Capacitor Discharge — •Stefan Küchemann[1], Jonas Rübsam[1], Carsten Mahn[1], Marios D. Demetriou[2], William L. Johnson[2], and Konrad Samwer[1] — [1]1. Physikalisches Institut, Universität Göttingen, 37077 Göttingen, Germany — [2]Keck Engineering Laboratories, California Institute of Technology, Pasadena, California 91125, USA

Generally the study of the specific heat of metallic glasses is limited to temperatures below and close to T_G. The incipient crystallization process above the glass transition temperature prohibits the study of this quantity in the supercooled liquid region.

In this contribution specific heat measurements using a novel Multistep Rapid Capacitor Discharge (MRCD) technique are presented. With MRCD melt-spun Pd-, Ni- and Fe-based samples were heated up homogeneously with typical heating rates in the order of 10^6 K/s. The very high heating rates raise the stability of the undercooled melt and thus enlarge the temperature difference $\Delta T = T_X - T_G$ up to 400 K or even suppress crystallization completely.

After a first capacitor discharge the sample reaches the supercooled liquid region while under nearly adiabatic conditions additional discharges allow specific heat measurements in the undercooled liquid.

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