MM 6: Liquid and Amorphous Metals II: Shear bands

Time: Monday 11:30–13:00 Location: H52

MM 6.1 Mon 11:30 H52

Nucleation and propagation of shear bands in metallic and network-forming glasses — •Richard Jana and Lars Pastewka — Institut für Angewandte Materialien - Computational Materials Science, Karlsruher Institut für Technologie (KIT), Karlsruhe, Deutschland

Molecular Dynamics simulations (MD) were used to study nucleation and propagation of shear bands during simple shear deformation of CuZr binary bulk metallic glasses (BMG), amorphous silicon (a-Si) and amorphous carbon (a-C). We find that the initial shear bands in a-Si and a-C are more localized than those found in CuZr. Shear bands in a-Si and a-C can be easily morphologically distinguished from their bulk from simple parameters such as the local coordination number and density. While such a clear signature of shear-banding is not found in local topological parameters for CuZr, such as short-range order (SRO) determined by Voronoi tessellation, we show by repeated deformation and quench sequences that in neither case dynamic shear localization through viscous heating and subsequent local softening is the cause of the localization. Nevertheless, thermal effects show impact on the shear localization, as shear bands vanish at elevated temperatures even below Tg. We correlate the temperature-dependence of coordination number and SRO with with the evolution of shear banding at elevated temperatures.

MM 6.2 Mon 11:45 H52

Nonlinear Response in Metallic Glasses under Mechanical Excitation — •Birte Riechers and Konrad Samwer — 1st Physics Department, Georg-August-University Göttingen, Germany

As stress-strain-curves of metallic glasses show, these materials can easily be driven from linear behavior at low mechanical fields to the nonlinear regime by applying comparably high mechanical fields at fixed temperature.

This provides a promising opportunity for investigating the effects of external fields on the relaxation mode spectrum. If the nonlinear regime is entered by using high strains, changes in the shape of the potential energy landscape are expected. This results in a redistribution of relaxation modes and even leads to changes in the shape of the relaxation mode spectrum. MD-simulations on metallic glasses [1,2] have shown this tremendous impact, and predict a transition from fragile to strong behavior.

In this experimental work, the influence of high mechanical strain on the metallic glass $Pd_{40}Ni_{40}P_{20}$ is investigated. The change of the overall relaxation mode spectrum is analyzed with a focus on the behavior of α- and β-processes. Also the redistribution timescale, which is the timescale on which the spectrum equilibrates to a change in external field [3], will be compared to timescales inherent to the relaxation processes of the system.

Financial support by the DFG Research Unit FOR 1394. [1]: H.-B. Yu, Nat. Comm. 6, 2015; [2]: H.-B. Yu, Phys.Rev.B 90, 144201, 2014; [3]: B. Riechers, J. Chem. Phys. 142, 2015;

MM 6.3 Mon 12:00 H52

Physical insights into the mechanisms of tensile creep of a $Pd_{40}Ni_{40}P_{20}$ Bulk Metallic Glass — •Isabelle Binkowski[1], Sergiy V. Divinski[1,2], and Gerhard Wilde[1,3] — [1]Institute of Materials' Physics, University of Münster, Wilhelm-Klemm-Str. 10, D-48149 Münster, Germany — [2]National University of Science and Technology "MISiS", Leninsky pr.4, Moscow, Russia — [3]Institute of Nanochemistry and Nanobiology, Shanghai University, Shanghai 200072, China

Bulk metallic glasses (BMGs) are known for their high elastic limit, high yield strength, high hardness, corrosion resistance and soft magnetic properties. However, engineering requires a suitable amount of deformability, which, in the case of bulk metallic glasses, is lacking. At sufficiently low temperatures (below T_g) or at high strain rates, deformation of BMGs proceeds inhomogeneously via the formation of thin 2D-like regions of localized strain, so-called shear bands, whose continued activation lead to a catastrophic failure.

For fundamental investigations of properties and mechanisms of shear banding, a $Pd_{40}Ni_{40}P_{20}$ BMG is used, due to its high thermal stability against crystallization in a wide temperature range. A set of miniaturized tensile creep tests is performed at constant stress conditions to give further insights into the shear band events and shear band interactions. The tests are performed in the temperature range between 413 K to 443 K and the stress is fixed at 900 MPa which is about 60% of the yield stress.

A financial support of DFG via SPP 1594 is acknowledged.

MM 6.4 Mon 12:15 H52

Creep of Cu-Zr glass composites studied by Molecular Dynamics simulations — •Constanze Kalcher, Tobias Brink, Alexander Stukowski, and Karsten Albe — FG Materialmodellierung, FB Materialwissenschaft, Technische Universität Darmstadt, Germany

Over the past two decades, the mechanical properties of metallic glasses have been studied intensively. It is widely accepted that their deformation at low temperature is heterogeneous and that in this regime shear bands can occur. However, when considering high-temperature applications, closer to the glass transition temperature, $T > 0.6\,T_g$, the possibility of plastic deformation through creep has to be taken into account. In contrast to crystals, where one can clearly distinguish between three different creep stages, the mechanisms behind high-temperature creep behavior of amorphous alloys is still unclear. In this work we compare a homogeneous $Cu_{64}Zr_{36}$ glass with glass-crystal (B2 Zr) composites with different topologies: a) interpenetrating network b) rods and c) embedded particles. While the pristine metallic glass deforms homogeneously, the glass-crystal composites form shear transformation zones at the glass/crystal interfaces. Furthermore, we show what influence the topology of the interfaces has on the creep behavior and its activation energy.

MM 6.5 Mon 12:30 H52

A Molecular Dynamics Simulation Study On The Avalanche Dynamics And The Microstructure Evolution Of The Glassy Cu50Zr50 System. — •Alexandra Lagogianni and Konrad Samwer — Erstes Physikalisches Institut, Goettingen, Deutschland

The presence of avalanches/stress drops in the plastic regime of BMGs upon mechanical deformation, and their direct correlation with the formation and arrest of single shear bands [1-2], has been revealed by several experimental studies the last decades. Aiming to gain a deeper insight of this phenomenon on a smaller length scale we employed molecular dynamics simulations of an amorphous CuZr system under tension. Different strain rates were tested at room and glass transition temperature and the distribution of stress drops sizes was found to follow a power law which exponent is in agreement with that predicted by the avalanche dynamics theory [3]. It came out that the serrated flow takes place even from the very beginning of the elastic region while the possible alterations that occur in the microstructure of the system were exhaustively studied. The present simulation results provide a theoretical confirmation of the experimental findings and a deeper and qualitative understanding of the origin of avalanches in a metallic glass.

[1] Krisponeit, J.O, Pitikaris S., Avila K.E., Küchemann, S., Krüger, Samwer ,K. Nature Communications 5, 3616 (2014). [2] Dalla Torre, F.H., Dubach, A., Nelson A., Löffler J.F. Materials Transactions 48, 7, pp. 1774-1780 (2013). [3] Dahmen K.A, Ben-Zion Y., Uhl J.T. Nature Physics 7 pp. 554-557 (2011).

MM 6.6 Mon 12:45 H52

Avalanches upon the deformation process in metallic glasses — •Carlos Herrero-Gomez and Konrad Samwer — I Physikalisches Institut, Universität Göttingen

Bulk metallic glasses respond with elastic and/or plastic deformation to applied mechanical stresses. Such deformation is not a smooth response to the applied stress but instead take place via jerky jumps, which are often referred as Crackling Noise [1].

We report a statistical analysis of the crackling noise produced by metallic glasses during creep measurements. We present a waiting time analysis of such measurements. Such analysis reveals that the waiting time distribution follows a power law, in the same fashion of simulations and experiments of avalanche dynamics [2,3]. Furthermore, the study shows the existence of a crossover in the waiting times distribution [4]. The crossover was interpreted as a change in the deformation process. We performed a systematic analysis for different experimental conditions, to analyze the influence of the stress and temperature on the avalanche dynamics.

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[1] K. Dahmen, Y. Ben-Zion and J.T. Uhl. Phys Rev Let.102, 175501 (2009) [2] M.C: Kuntz, and J.P. Sethna. Phys. Rev. B, 62, 17 (2000) [3] J. Antonaglia, W.J. Wright, X.G. Ru, G.R. Byer, T. C. Hufnagel, M.Leblanc, J.T.U. and K.A. Dahmen.Phys. Rev. Let. 112, 155501 (2014) [4] J.O Krisponeit, S. Pitikaris, K.E.Ávila, S.Küchemann, A.Krüger and K. Samwer. Nat. Commun. 5, 3616 (2014)