MM 58: Liquid and Amorphous Metals

Mechanical Properties and Fracture

Time: Thursday 11:45–13:15 Location: TC 010

MM 58.1 Thu 11:45 TC 010

Mechanical and thermal properties of PdNiP based bulk metallic glasses — •Niklas Nollmann, Vitalij Hieronymus-Schmidt, Jonas Lübke, Harald Rösner, and Gerhard Wilde — WWU Münster

At low temperatures and high stresses bulk metallic glasses (BMGs) deform inhomogeneously and suffer from a lack of ductility making BMGs unsuitable for many applications. This inhomogeneous deformation can be described in the frame work of a 'fictive temperature' concept with free volume as a key parameter. An increment or redistribution of the present free volume can be achieved in different ways: i) cryogenic rejuvenation or ii) micro-alloying [2]) may lead to enhanced ductility. In our study we investigated $Pd_{40}Ni_{40}P_{20}$ based bulk metallic glasses in detail: Adding small amounts of Iron or Cobalt to the $Pd_{40}Ni_{40}P_{20}$ metallic glass leads to huge changes in ductility. These effects on the mechanical properties by micro-alloying were monitored in bending and compression tests. We also calculated the critical fictive temperature for these different $Pd_{40}Ni_{40}P_{20}$ based BMGs to show the influence of annealing on the plasticity which is directly linked to the influence of free volume. Moreover, the effects of different degrees of cryogenic rejuvenation due to changes in cycle numbers and resting times at different temperatures of the same metallic glass were investigated with respect to the amount of free volume and the mechanical properties.

MM 58.2 Thu 12:00 TC 010

Novel atomic-level mechanism governing shear banding in metallic glasses — •Daniel Şopu[1,2], Alexander Stukowski[1], Mihai Stoica[3], and Sergio Scudino[4] — [1]Institut für Materialwissenschaft, Technische Universität Darmstadt, Otto-Berndt-Straße 3, D-64287 Darmstadt, Germany — [2]ErichSchmid Institute of Materials Science, Austrian Academy of Sciences, Jahnstrasse 12, A-8700 Leoben, Austria — [3]ErichSchmid Institute of Materials Science, Austrian Academy of Sciences, Jahnstrasse 12, A-8700 Leoben, Austria — [4]IFW Dresden, Institut für Komplexe Materialien, Helmholtzstraße 20, D-01069 Dresden, Germany

The most conceivable scenario of shear band formation is the percolation of shear transformations zones (STZ) along a viable plane of maximum shear stress. However, despite the recent research progress, how an autocatalytic chain reaction of STZ takes place in a metallic glass remains a critical question that has not been resolved so far in the field. Here, by using molecular dynamics simulations, we provide a new atomic-level mechanism underlying the STZ percolation process. The mechanism is based on the autocatalytic generation of successive strong strain and rotation fields, leading to STZ percolation and, ultimately, to the formation of a shear band. The results build a bridge between the discrete nature of STZs at the atomic-level and the rather continuous character of shear bands at the microscale. We suggest that our results may have significant implications for understanding several aspects characterizing the process of shear banding in metallic glasses and other disordered materials.

MM 58.3 Thu 12:15 TC 010

Effect of elemental segregation on mechanical properties of metallic nanoglasses — •Sree Harsha Nandam[1], Ruth Schwaiger[2], Di Wang[1], Reda Chellali[1], Yulia Ivanisenko[1], and Horst Hahn[1] — [1]Institute of Nanotechnology, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Institute for Applied Materials, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

Metallic nanoglasses represent a new class of non-crystalline solids with excess free volume at the interfaces. Because such interfaces can act as nucleating sites for shear during plastic deformation, nanoglasses have enhanced plasticity compared to a conventional metallic glass. In this paper, the effect of elemental segregation at the interfaces on mechanical properties of Pd-Si and Cu-Zr binary metallic nanoglasses synthesized by inert gas condensation is studied. The amorphous nature and nanosize of the particles is confirmed by X-ray diffraction and transmission electron microscopy. Elemental segregation in nanoscale is observed in Cu-Zr system while no such segregation is found in Pd-Si nanoglasses by atom probe tomography. Deformation behavior is studied by nanoindentation and micropillar tests. Homogeneous deformation is observed in Cu-Zr metallic nanoglasses whereas inhomogeneous deformation is observed in Pd-Si system. The effect of elemental segregation and the free volume in the metallic nanoglasses on their deformation behavior will be discussed in the present paper.

MM 58.4 Thu 12:30 TC 010

Local atomic order of a metallic glass made visible by scanning tunneling microscopy — •Yuansu Luo and Konrad Samwer — I. Physikalisches Institut, Georg-August-Universität, D-37077 Göttingen, Germany

STM investigations on quasi low-dimensional ultrathin films Zr65Cu27.5Al7.5 were carried out to explore atomic level structure of a locally ordered system. The highly oriented pyrolytic graphite (HOPG) was chosen as substrate. It creates imaging contrasts between long-range and short-range orders, so that the structural heterogeneousness arising from competition between the glass former and the epitaxy can be ascertained. For this purpose, the film is ultrathin in an order of magnitude corresponding to the scale of short range order (SRO). A chemical order predicted for this system was observed in atomic ordered regimes, accompanied with a charge density wave. This implies a chemical short range order (CSRO) in atomic disordered regimes, where polyhedral clusters are dominant with Cu(Al) in the center. An attempt was made for structural modeling based on high resolution STM images, giving icosahedral orders on surface and different Voronoi clusters in 3-D space.

MM 58.5 Thu 12:45 TC 010

Sensitivity for density change detection studied by scanning transmission electron microscopy image simulations — •Sven Hilke, Vitalij Hieronymus-Schmidt, Gerhard Wilde, and Martin Peterlechner — University of Münster, Institute of Materials Physics, Wilhelm-Klemm-Str. 10, 48149 Münster

Amorphous solids and metallic glasses have been in the focus of research for decades. Local diffraction experiments collecting many nano-beam diffraction patterns (NBDP) present a powerful tool to analyze amorphous structures. Recently the methods of Fluctuation Electron Microscopy (FEM) [1] as well as electron correlation microscopy (ECM) [2] were introduced in transmission electron microscopy (TEM). In the present study, the sensitivity of TEM methods to measure missing atoms in solids are analyzed. High angle annular dark field (HAADF) scanning TEM (STEM) is sensitive enough to detect signals of single atoms. It is the aim of this work to show that density changes can be quantitatively analyzed in crystalline silicon and amorphous copper zirconium (Cu64Zr36) by STEMcl [3], a STEM image simulation program.

[1] Voyles, P.M.; Muller, D.A.; Ultramicroscopy (2002), Volume 93, Issue 2, Pages 147-159.

[2] He, L.; Zhang, P.; Besser, M. F.; Kramer, M. J.; Voyles, P. M.; Microscopy and Microanalysis (2015), 21(04), 1026-1033.

[3]Radek, M.; Tenberge, J.-G.; Hilke, S.; Wilde, G.; Peterlechner, M.; Ultramicroscopy (2017), submitted.

MM 58.6 Thu 13:00 TC 010

In-situ observation of electron beam induced nanocrystallization of an ultra thin W foil — •Stefan Noisternig[1], Clemens Mangler[1], Christian Ebner[1], Christian Rentenberger[1], Hans-Peter Karnthaler[1], and Willem Tichelaar[2] — [1]University of Vienna, Physics of Nanostructured Materials, 1090 Vienna, Austria — [2]CEOS-GmbH, 69126 Heidelberg, Germany

An amorphous 2nm thin tungsten (W) foil supported by 3 nm carbon on a QUANTIFOIL grid is studied in an UltraSTEM 100 Nion dedicated scanning transmission electron microscope (STEM).

During the observation in the STEM the amorphous structure of W converts to a partially nanocrystalline one. The time to form the crystalline structure depends on the radiation dose of the electron beam. A Fast Fourier Transformation analysis of High Angle Annular Dark Field (HAADF) images reveals that WC0.82 and W3C0.375 nanocrys-

tals formed during the radiation of the amorphous W foil under the electron beam.

During the continuous acquisitions a movement of bright dots is observed in HAADF images. We interpret this phenomenon as an observed surface diffusion of W atoms which is here activated well below the knock-on energy (above 1 MeV) for W. Mean square displacements of bright dots are measured at amorphous areas and at crystalline areas. The calculated diffusion parameters are then compared to literature values obtained with different methods.

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