MM 46: Liquid and Amorphous Metals

Relaxation and Rejuvenation

Time: Wednesday 17:00–18:30 Location: TC 010

MM 46.1 Wed 17:00 TC 010

Analysis of a severely deformed $Pd_{40}Ni_{40}P_{20}$ bulk metallic glass — •Afrouz Hassanpour, Sergiy Divinski, Martin Peterlechner, and Gerhard Wilde — Institute of Materials Physics, Westfälische Welhilms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany

For practical usage of bulk metallic glasses (BMG) it is crucial to enhance material properties, such as tensile and compression ductility and fracture toughness. In the present work, $Pd_{40}Ni_{40}P_{20}$ bulk metallic glass was analyzed to study its behavior under conditions of severe deformation via high-pressure torsion (HPT). Amorphous samples were produced by copper mold casting in a melt spinner under argon atmosphere. X-ray diffraction, differential scanning calorimetry (DSC), and Transmission Electron Microscopy (TEM) were performed. The degree of deformation was systematically varied by applying different numbers of rotation with HPT from 0 (just compression) to 10 turns. HPT causes significant changes of the thermo-mechanical properties. It turned out, that unlike after deformation by cold-rolling, HPT deformation at room temperature induced a nanocrystallization transformation in the deeply undercooled liquid above the glass transition. Also structural relaxation by annealing and its impact on the nanocrystallization at higher temperatures was experimentally investigated for as-cast and HPT-processed states. The results are discussed in conjunction with dedicated TEM investigations for annealed and as-deformed amorphous samples.

MM 46.2 Wed 17:15 TC 010

Rejuvenation behavior and specific heat capacity of Pd40Ni40P20 bulk metallic glass influenced by severe plastic deformation — •Hongbo Zhou, Niklas Nollmann, René Hubek, Martin Peterlechner, and Gerhard Wilde — Institute of Materials Physics, University of Münster, Germany

The effects of severe plastic deformation (high pressure torsion, HPT) on rejuvenation behavior and specific heat capacity have been investigated. The results of differential scanning calorimetry (DSC) illustrate that the as-cast metallic glasses could be rejuvenated effectively during the HPT. The deformed state glasses possess much more structural relaxation enthalpy in contrast with the as-cast state, and an enhanced rejuvenation could be achieved with increasing deformation. Besides, it is assumed that atomic re-arrangements take place as a consequence of HPT because the deformed state glasses have an apparently different crystallization behavior compared to the as-cast state. The results of low-temperature specific heat capacity measurements using a physical properties measurement system (PPMS) reveal that the heights of boson peak increase with a similar trend as function of strain. Moreover, the effects of rejuvenation on the mechanical properties will be discussed.

MM 46.3 Wed 17:30 TC 010

Elastostatic Reversibility: Structural Changes in Thermoplastically Formed Metallic Glass — •Baran Sarac[1], Christoph Gammer[1], Liang Deng[2], Eunmi Park[2], Yoshihiko Yokoyama[3], Mihai Stoica[4], and Jürgen Eckert[1] — [1]Erich Schmid Institute, Leoben, Austria — [2]IFW Dresden, Dresden, Germany — [3]Tohoku University, Sendai, Japan — [4]ETH Zurich, Zürich, Switzerland

Albeit high processing capabilities of BMGs, thermoplastic forming (TPF) can severely degrade their mechanical and physical properties. Present work places an importance on elastostatic loading (ESL) which not only fully recovers the lowered room temperature plasticity originated from TPF or post-cryostatic conditions, but also activates a rejuvenation mechanism by yielding an extended resistance against strain softening. The drop in the supercooled liquid region and crystallization enthalpy measured by differential scanning calorimeter are found to be temporary, and can be reversed to its initial condition. Individual nanobeam diffraction patterns taken by the fluctuation electron microscopy are acquired with a probe size of 1.2 nm. Normalized variance of a series of nanodiffraction patterns of the post-ESL sample reveals height decrease in the first broad peak of normalized intensity variance, suggesting the modifications in the medium-range order which in turn dramatically restores mechanical and thermal properties. The combination of TPF and post-ESL treatment in BMGs can open a new avenue for ultra-high mechanical and thermal performance micro- and nanomechanical devices for biosensors, MOSFETs, and robotics.

MM 46.4 Wed 17:45 TC 010

Cryogenic Cycling of Bulk Metallic Glasses — •Jonas Lübke, Niklas Nollmann, Martin Peterlechner, and Gerhard Wilde — Institute of Materials Physics, WWU Münster, Germany

Metallic glasses show interesting properties, such as high strength, toughness and corrosion resistance. However, a severe lack of ductility makes the material unsuitable for many applications. In the past, much effort was made on reducing this disadvantage using micro-alloying or crystalline precipitates with some notable success. A different approach is provided by the concept of free volume in metallic glasses, where the increment of such may lead to enhanced ductility. This so called rejuvenation was already achieved by severe plastic deformation and shot-peening. However, Ketov et al. [1] claim to achieve this rejuvenation by using the heterogeneous thermal expansion coefficient of metallic glasses to induce internal strain by thermal cycling, which could lead to increased free volume. To avoid structural relaxation, these cycles have to be at cryogenic temperatures. By this, the ductility of the metallic glass is said to be improved in a different and simple way which would make the material suitable for new applications.

The effects of different amounts of cryogenic cycles on the well-known metallic glass $Zr_{41.2}Ti_{13.8}Cu_{12.5}Ni_{10}Be_{22.5}$ (VIT1) and its free-volume, by analysing thermal- and mechanical properties, are presented and discussed.

[1] S. V. Ketov et al. Rejuvenation of metallic glasses by non-affine thermal strain. Nature 524, 2015

MM 46.5 Wed 18:00 TC 010

Abnormal structural relaxation spectrum observed by dynamic mechanical analysis in an Au-based bulk metallic glass — •Maximilian Frey, Nico Neuber, Isabella Gallino, and Ralf Busch — Chair of Metallic Materials, Saarland University, C6.3, 66123 Saarbrücken, Germany

The structural relaxation time spectrum of a recently developed gold-based metallic glass former is investigated via isochronal temperature scans performed with a dynamic mechanical analyzer. The α-relaxation event for each applied measurement frequency manifests as a maximum in the loss modulus curve. The respective frequency-temperature data points are pictured in an Arrhenius plot and used to evaluate the temperature dependence of the structural relaxation time in the framework of Angell's fragility concept. At low measurement frequencies, the supercooled liquid exhibits a strong temperature dependence, which is in agreement with recent results obtained by calorimetric and thermomechanical studies. For intermediate frequencies, the single maximum peaks of the loss modulus curves perform an unusual splitting in several distinguishable peaks. By further increasing the measuring frequencies, the normal single peak appearance is restored, but with a distinctly more fragile temperature behavior. Calorimetric and thermomechanical studies are performed and compared to the dynamic mechanical data set. Taking recent literature findings for similar alloys into account, the results can be most likely interpreted as the fingerprint of a strong-to-fragile transition event.

MM 46.6 Wed 18:15 TC 010

The Stokes-Einstein relation of a simple liquid metal and its relationship to changes in the microscopic dynamics with increasing temperature: the experimental viewpoint — •Franz Demmel — ISIS Facility, Didcot, UK

For liquid rubidium the Stokes-Einstein-relation is well fulfilled near the melting point with an effective hydrodynamic diameter, which agrees with a value from structural investigations. A wealth of thermodynamic and microscopic data exist for a wide range of temperatures for liquid rubidium and hence it represents a good test bed. With increasing temperature the SE-relation shows a departure from the expected temperature behaviour. That temperature range coincides with an observed change in the microscopic relaxation dynamics on nearest neighbor distances [1]. The derived average relaxation time for density fluctuations on this microscopic length scale shows a non-Arrhenius behaviour. Combining the experimental macroscopic self-diffusion coefficient with the average relaxation time, a violation of the SE-relation at the same temperature range can be demonstrated. Simulations and experimental results from other metals and alloys demonstrate a similar behavior and point to a possible universal change in the dynamics of liquid metals [2]. [1] F. Demmel et al, Phys. Rev. B 73, 104207 (2006) [2] F. Demmel et al, J.Phys.: Condens. Matter 27 455102 (2015); A. Jaiswal et al, Phys. Rev. Lett. 91 205701 (2016); X.J. Han and H.R. Schober, Phys Rev B 83 224201 (2011)