MM 40: Liquid and Amorphous Metals

Session: Relaxation, ageing and rejuvenation

Time: Thursday 15:00–16:15 Location: H46

MM 40.1 Thu 15:00 H46

Long-range strain correlations in 3D quiescent glass forming liquids — •Muhammad Hassani and Fathollah Varnik — ICAMS, Ruhr-Universität Bochum, 44801, Bochum, Germany

Recent 2D computer simulations and experiments indicate that supercooled liquids and glasses exhibit long-lived, long-ranged strain correlations in the unperturbed quiescent state [1, 2]. Here we investigate this issue in three dimensions via molecular dynamics simulations of a glass forming binary Lennard Jones mixture. Both in the glassy state and in the supercooled regime, strain correlations are found to decay with a $1/r^3$ power-law behavior, reminiscent of elastic field around an inclusion. Moreover, theoretical predictions on the time dependence of the correlation amplitude are in line with the results obtained from simulations. It is argued that the size of the domain, which exhibits a "solid-like" strain pattern in a supercooled liquid, is determined by the product of the speed of sound with the structural relation time. While this length is of the order of nanometers in the normal liquid state, it grows to macroscale when approaching the glass transition [3, 4].

[1] B. Illing, S. Fritschi, D. Hajnal, C. Klix, P. Keim, and M. Fuchs, Phys. Rev. Lett. 117, 208002 (2016).

[2] K.E. Jensen, D.A. Weitz and F. Spaepen, Phys. Rev. E 90, 042305, (2014).

[3] M. Hassani, P. Engels, and F. Varnik, Europhys. Lett., 121(1):18005, (2018).

[4] M. Hassani, E. M. Zirdehi, K. Kok, P. Schall, M. Fuchs, and F. Varnik, Europhys. Lett., 124(1):18003, (2018).

MM 40.2 Thu 15:15 H46

The relaxation dynamics of a severely deformed metallic glass studied by X-ray photon correlation spectroscopy — •Hongbo Zhou[1], Sven Hilke[1], Eloi Pineda[2], and Gerhard Wilde[1] — [1]Institute of Materials Physics, University of Münster, 10 Wilhelm-Klemm Strasse, Münster 48149, Germany — [2]Department of Physics, Universitat Politecnica de Catalunya BarcelonaTech, Esteve Terradas 8, Castelldefels 08860, Spain

The structural relaxation behavior of a metallic glass severely deformed by High- Pressure Torsion was investigated at the atomic length scale by high-resolution X-ray photon correlation spectroscopy. We find that the dynamics of the deformed sample is much faster compared with the undeformed sample, indicating that rejuvenation has occurred. Meanwhile, the structural relaxation rates and behaviors of both samples are distinct at different temperatures. It is notable that an intermittent and heterogeneous relaxation process happens at the temperature of 423 K. The activation energies of the structural relaxation below 473 K are 21.2 kJ/mol and 25 kJ/mol respectively, which demonstrates that the relaxation processes at low temperatures are stress-dominated. However, when the temperature is increased above 473 K, a crossover behavior of the effective relaxation time occurs, which is probably due to a change of relaxation mechanisms from a stress-dominated to a diffusion-dominated process.

MM 40.3 Thu 15:30 H46

Characterization of CuZr-based bulk metallic glasses rejuvenated by severe plastic deformation — Christian Ebner[1], Benjamin Escher[2], Christoph Gammer[3], Jürgen Eckert[3], Simon Pauly[2], and •Christian Rentenberger[1] — [1]University of Vienna, Physics of Nanostructured Materials, Vienna, Austria — [2]Leibniz Institute for Solid State and Materials Research Dresden, Institute for Complex Materials, Dresden, Germany — [3]Austrian Academy of Sciences, Erich Schmid Institute of Materials Science, Leoben, Austria

Bulk metallic glasses (BMGs) are materials composed of metal components but lack long-range order. The latter renders BMGs unique in their mechanical properties. Nevertheless, they exhibit also a low ductility caused by a very localized plastic deformation. Therefore, it is one of the challenging aims to find ways and processes for improvements. In this work we show that severe plastic deformation of BMGs facilitates a rejuvenation of the disordered atomic structure that was characterized by various methods including Synchrotron X-ray diffraction, nanoindentation, differential scanning calorimetry, atomic force and transmission electron microscopy. By a unique and unprecedented mapping of structural and mechanical quantities on micrometer scale a clear correlation both between elastic and plastic softening and between softening and mean atomic volume can be revealed [1]. Finally, based on nanoindentation curves it is concluded that structural rejuvenation promotes a more homogeneous like deformation.

[1] C. Ebner et al., Acta Mater 160 (2018) 147.

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MM 40.4 Thu 15:45 H46

Impact of cryogenic rejuvenation on calorimetric and kinetic properties of plastically deformed $Pd_{40}Ni_{40}P_{20}$ bulk metallic glass — •Afrouz Hassanpour, Sergiy V. Divinski, Martin Peterlechner, and Gerhard Wilde — Institute of Materials Physics University of Münster Wilhelm-Klemm-Str. 10 48149 Münster Germany

In metallic glasses, plastic deformation at ambient conditions is typically localized in shear bands. In the present work, the impact of different types of deformation, namely of high-pressure torsion (HPT) and cold rolling, and the effect of subsequent cryogenic rejuvenation are analyzed for the $Pd_{40}Ni_{40}P_{20}$ bulk metallic glass. Different experimental techniques are applied to examine the structural changes due to the plastic flow, including X-ray diffraction, differential scanning calorimetry and the radiotracer diffusion measurement. Using HPT processing, extremely large shear deformation is imposed under quasi-hydrostatic conditions. The plastic flow during deformation likely increases the excess free volume in the material and affects the local atomic configurations. We report on an increase of the diffusion rates in the deformed samples in comparison to the as-cast ones and the impact of cryogenic rejuvenation on the diffusion enhancement. Shear bands are shown to represent short-circuit paths for diffusion and their relaxation is discussed.

MM 40.5 Thu 16:00 H46

Decelerated Ageing in Binary Metallic Glasses by Cryogenic Thermal Cycling — •Marian Bruns and Fathollah Varnik — Ruhr Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany

Cryogenic thermal cycling is a thermal treatment where samples are exposed to an oscillatory temperature change at low temperatures. For its application to metallic glasses, cycling temperatures sufficiently below the glass transition temperature T_G are employed to avoid thermally activated relaxation or annealing. It has been proposed that cryogenic thermal cycling leads to rejuvenation of aged glasses, thus improving their plasticity.

Here, we investigate this issue via molecular dynamics simulations. In contrast to previous studies, addressing static properties, we focus on dynamic aspects. We qualitatively indicate ageing, rejuvenation and their extend by comparing the *mean squared displacement* of as-aged and as-cycled systems. The treatment has been performed at both constant volume and constant pressure with different frequencies, depending on the time the system aged prior to the cycling. We find that the glassy system as we prepared it is not being rejuvenated by the treatment but further ageing during the cycling is observable. Nonetheless the treatment has an impact on the ageing process by slowing it remarkably down. This indicates that processes that cause ageing (i.e. structural relaxation) are in a competitive relation with processes related to rejuvenation due to thermal treatment.