# Mechanical behaviour of bulk metallic glasses and nanocomposites by in-situ X-ray diffraction

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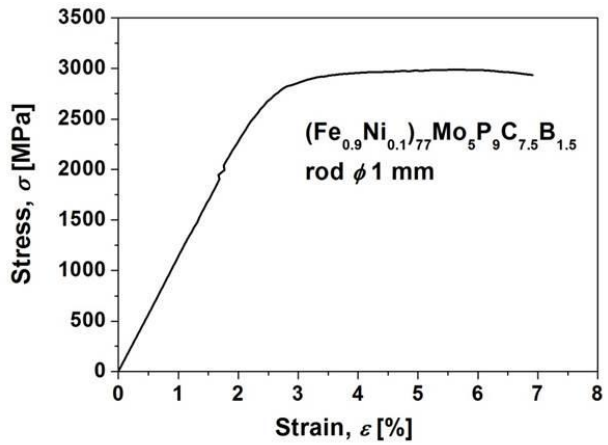
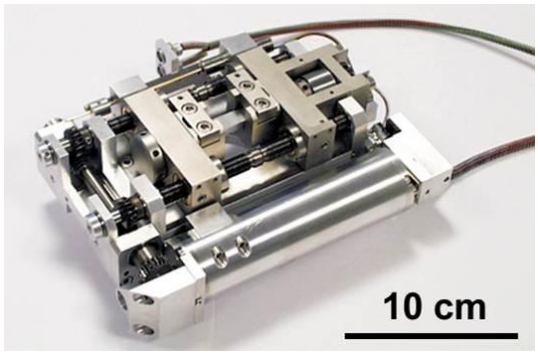
The principal aim of the proposed experiment was to study the (micro-, nano-) crystallization and/or phase transformation of amorphous and (nano-) composite samples subjected to compressive load. High strength has been a long-standing objective pursued in metals and alloys. Bulk metallic glasses (BMGs) have strengths approaching the theoretical limit [1] but their plasticity at room temperature is typically very low. Plastic deformation of metallic glasses at room temperature occurs through the formation and evolution of shear bands, and is localized within the shear bands [2]. Therefore, brittleness is regarded as an intrinsic defect of metallic glasses. Several properties of amorphous materials including fatigue, fracture, and component performance are governed by the magnitude of strain fields around heterogeneities such as local compositional variations, crystalline inclusions, voids, or cracks. Efforts have been made to enhance the plasticity of BMGs, mostly focusing on the fabrication of BMG composites [3,4]. One of the hot topics is to enhance the plastic deformation of Fe-based BMGs, because, besides the low cost determined by the cheap elements used for their fabrication, they have outstanding soft magnetic properties, all together making them very attractive for applications. Very recently, a new FeNiMoPCB BMG with more than 8.5% plastic deformation was developed at IKM, IFW Dresden [5].This remarkable extended plastic deformation (i.e. never measured up to now for a monolithic BMG, neither for Fe-based nor for Zr-based alloys) was believed to be determined by the in-situ formed crystalline nuclei or nanocrystals which may hinder the crack propagation, as in the typical case of Zr-based BMGs [6]. For the current experiment, cylindrical BMG samples of 1 and 2 mm diameter and with aspect ratio 2:1 were prepared in advance at the home institute (IFW Dresden). Fig. 1 shows the stress-strain curve of the sample measured simultaneously with X-ray diffraction at BW5. The details of the experimental set-up are presented in Fig. 1 as well. The mechanical testing device can be placed in the X-ray beam and the opening of the clamping pieces do not produce additional reflexes or shadows on the diffraction image collected by a fast 2D detector.



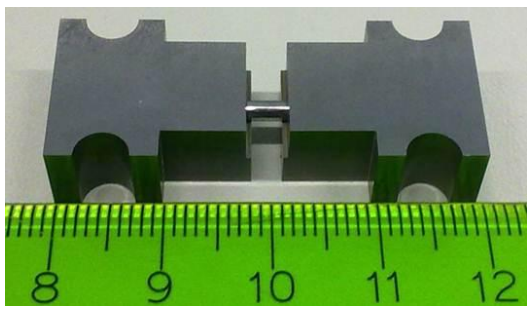




Fig. 1 The stress-strain curves (picture above) measured using a 5 kN Kammrath&Weiss tensile/compressive rig (right picture, up). The picture in the right, down side, shows the sample environment.

The collected experimental data enable simultaneous evaluation at least three different aspects: (i) stress-strain behaviour, (ii) possible structural modification(s) by analysing the structure factor in reciprocal space and/or short and medium range order in direct space, and (iii) the induced anisotropies during mechanical load by analysing the shape of the diffraction broad rings.

The current XRD experiment did not reveal formation of crystals or nanocrystalls during loading and unloading. The samples remained fully amorphous from the beginning up to the moment of fracture. Fig. 2 shows for comparison two diffraction images. Besides the absence of any sharp ring, proving the amorphous nature of the sample, one can clearly see there that the broad rings (fig. A, zero applied load) become elliptical upon load (fig. B, ~ 3000 MPa, just before fracture). The dotted circle (Fig. 2 A) and ellipse (Fig. 2 B) are added as guides for the eyes. This shows a significant anisotropy in the glass induced by the mechanical load. From the angular dependence of the position of the first peak of the XRD scattered intensity (Fig. 3), the strain tensor components can be calculated [7]. Further, analysing the changes in the short/medium range order one can obtain a complete picture of the mechanical behaviour of the bulk metallic glass upon load/unload. This work is currently being performed.

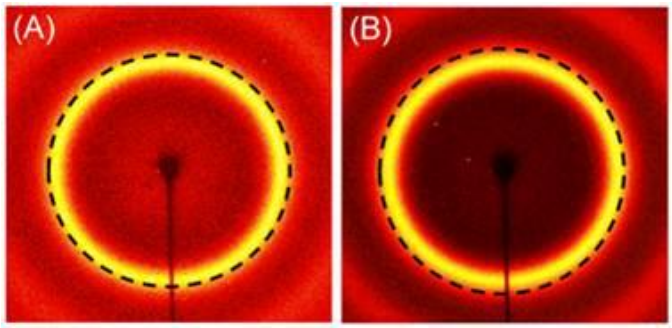



Fig. 2 Diffraction image from a 2D detector, with the sample under (A) zero applied load and (B) almost 3000 MPa (compressive load).

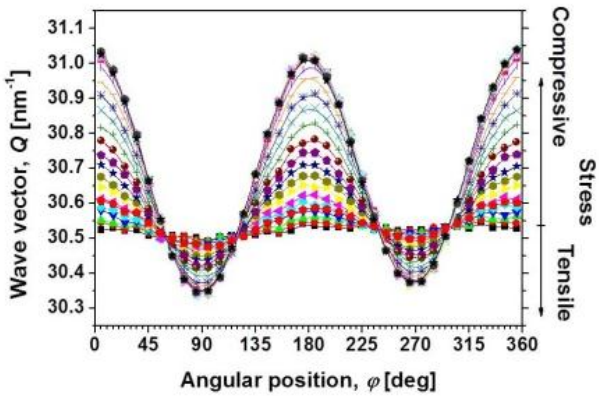



Fig. 3 Angular dependence of the wave vector at various stages of deformation. The full lines denote fits of the experimental data. The angular positions 0°/180°/360° correspond to the compression direction.

## References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