Tensile deformation studies of $Fe_{72.5}Cu_1Nb_2Mo_2Si_{15.5}B_7$ glassy ribbons at elevated temperatues using XRD

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Introduction

It has been recently shown and confirmed that the high energy X-ray diffraction (XRD) can be successfully used for determining of strain distributions not only in crystalline but as well in disordered materials such as metallic glasses [1-3]. The aim of the work was to observe the transition from elastic to plastic deformation during tensile experiments at elevated temperatures in the case of a $Fe_{72.5}Cu_1Nb_2Mo_2Si_{15.6}B_7$ glassy alloy using high-energy XRD.

Experiment

Amorphous ribbons with nominal composition $Fe_{72.5}Cu_1Nb_2Mo_2Si_{15.5}B_7$ and having thickness and witdh of 30 μm and 9 mm, respectively, were prepared by a single-roller melt spinning technique. The measurements were carried out with a multipurpose diffraction instrument at the beamline BW5 at HASYLAB/DESY. Specimens were strained under tension using a test rig from Kammrath und Weiss GmbH equipped with a resistance ceramics heater covering temperatures from 20°C up to 700°C. The continuous increase of load was performed in an elongation control mode during isothermal sample heating. The x-ray diffraction experiment was realized in a transmission geometry as it is shown in figure 1. Diffracted photons were acquired using an area detector Perkin Elmer 1621 carefully aligned orthogonally to the incoming X-ray beam.

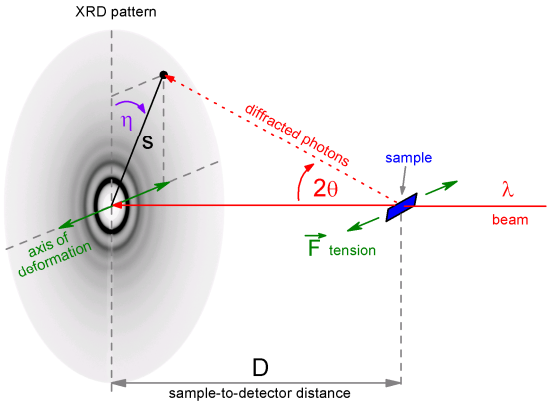

Figure 1: Sketch of an in situ tensile experiment in which (η, s) represent coordinates of the polar coordination system in respect to the plane of a 2D diffraction pattern.

Results

The measured 2D diffraction pattern was equally divided into 36 segments with respect to the polar coordinate η and obtained particular cakes were then radial integrated using the software package FIT2D [4]. The procedure was repeated for all diffraction patters collected at different loads. In this manner, one obtains intensity distributions $I(Q, \eta, \sigma)$ where σ refers to a corresponding stress. Fig. 2 shows the evolution of a main peak position with the increase of the applied tensile stress for transversal (η = 90°) and longitudinal (η = 0°) directions. The increase in the peak position with increasing tensile stress reflects the fact that atoms move closely to one another along the direction (η = 90°)) perpendicular to the direction of the applied tensile stress. An opposite trend is observed in the longitudinal direction. Following a relative change in the position of the first peak upon applying an external stress the strain distribution $\varepsilon(\eta, \sigma)$ for corresponding σ can be calculated [1]. Fitting the strain angular distribution using a formula

$$\varepsilon(\eta,\sigma) = \varepsilon_{11}\sin^2\eta + \gamma_{12}\sin\eta\cos\eta + \varepsilon_{22}\cos^2\eta$$

resulted in determining of the strain tensor components, namely longitudinal ε_{11}, transversal ε_{22} and in-plane shear component γ_{12}. Finally we have obtained the stress-strain diagram plotted in fig. 3 for strain tensor components at different temperatures of isothermal heating. It is seen that in the case of the tensile experiments performed at the temperature 420°C the small region of a plastic deformation is undoubtedly observable. Both samples fractured at stresses below 1500 MPa which correspond to lower values than the values that have been reported in situation of room temperature experiments [5].

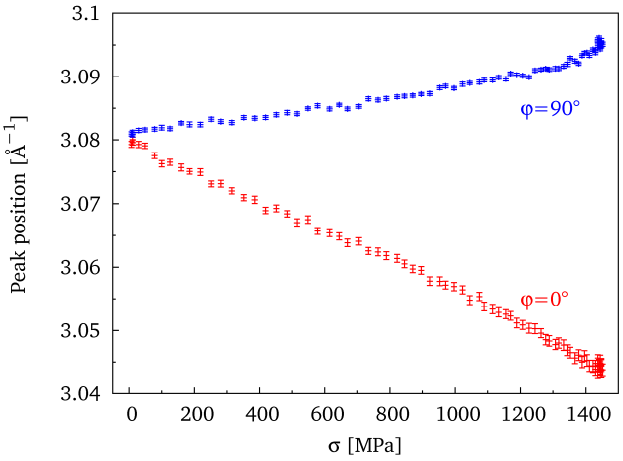

Figure 2: Change in the first peak position with applied tensile stress.

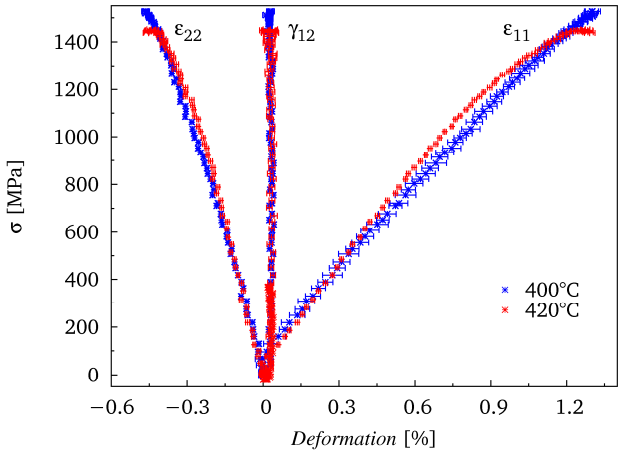

Figure 3: Stress-strain curves for different strain tensor components obtained at temperatures 400°C and 420°C.

References

[1] H.F. Poulsen, J.A. Wert, J. Neuefeind, V. Honkimäki and M. Daymond, Nat. Mater. **4**, 33 (2005)

[2] J. Das, M. Boström. N. Mattern, Å. Kvick, A.R. Yavari, A.L. Greer and J. Eckert, Phys. Rev. B **76,** 092203 (2007)

[3] X.D. Wang, J. Bednarcik, K. Sakls, H. Franz, Q.P. Cao and J.Z. Jiang, Appl. Phys. Lett. **91**, 081913 (2007)

[4] A.P. Hammersley, S.O. Svensson, M. Hanfland, A.N. Fitch and D. Häusetmann, High Press. Res. **14**, 235 (1996)

[5] J. Bednarcik. S. Michalik and H. Franz, Journal of Alloys and Compounds, doi:10.1016/jallcom.2010.12.007