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## Report:

The tensile deformation of the $Zr_{64.13}Cu_{15.75}Ni_{10.12}Al_{10}$ (S2 series) bulk metallic glasses in the form of as-casted sheets and sheets rolled to different extent was investigated by *in-situ* angular-dispersive X-ray diffraction (XRD) at the ID15B wiggler beamline in ESRF (Grenoble, France). The dog bone shaped samples were strained under tension (Kammrath and Weiss GmbH straining system with a maximum load of 5 kN) at room temperature. The tensile load was continuously increased at the constant rate of 0.5 N/s. The synchrotron radiation wavelength was set to $\lambda$ = 0.1429 Å (equivalent to the photon energy of 86.763 keV). The diffraction experiments were carried out in the transmission geometry. $LaB_6$ standard was used to calibrate the sample-to-detector distance and tilt of the imaging plate relative to the beam path. The sample was continually illuminated by well collimated incident beam having cross section of 0.4x0.4 $mm^2$. XRD patterns were collected using a fast, large area PIXIUM 4700 detector (2640x1920 pixels, having pixel size of 154x154 $\mu m^2$) carefully mounted orthogonal to the x-ray beam. To avoid detector overexposure we set the maximum exposure time to 0.4 s. Summing up of 50 consequent two-dimensional diffraction images resulted in an excellent signal-to-noise ratio while providing reasonable time resolution (20s) for in-situ experiment. The strain determination of bulk metallic glasses from XRD data is based on concepts previously reported by Poulsen *et al* [1]. The two-demensional diffraction patterns were divided into 36 pies, each having opening of 10 degrees. Corresponding strain tensor components were calculated from the angular dependence of the principal diffuse peak position. Repeating this procedure for different stages of deformation we obtained strain-stress curves $\sigma=\sigma(\varepsilon)$ as observed in tensile ($\varepsilon_{11}$) and transversal direction ($\varepsilon_{11}$).

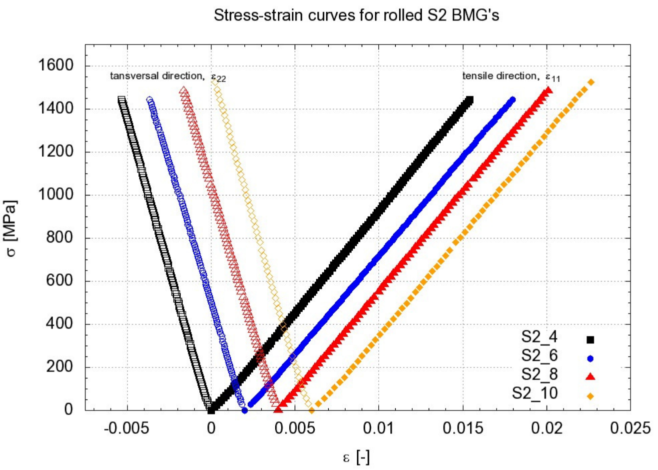


*Fig.1* Stress-strain curves of pre-rolled $Zr_{64.13}Cu_{15.75}Ni_{10.12}Al_{10}$ (S2 series) BMGs as observed by in-situ XRD in tensile ($\varepsilon_{11}$) and transversal direction ($\varepsilon_{11}$). For purposes of better clarity all curves are horizontally offset by 0.002.

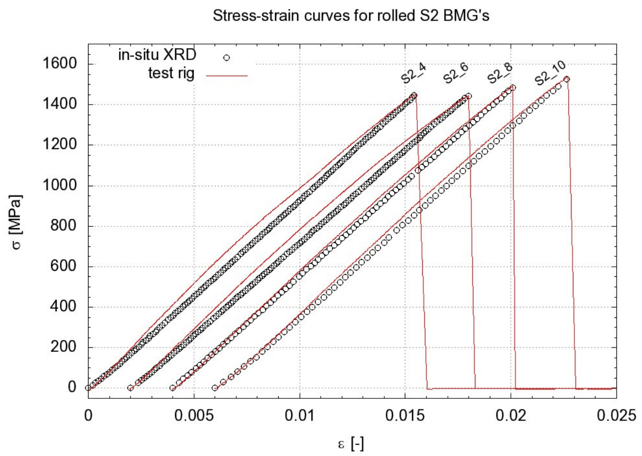


*Fig.2* Comparison of stress-strain curves as obtained by conventional measurement using test-rig (red line) and in-situ XRD (open circles).

Figure 1 shows stress-strain curves of pre-rolled $Zr_{64.13}Cu_{15.75}Ni_{10.12}Al_{10}$ (S2 series) BMGs as observed by in-situ XRD in tensile ($\varepsilon_{11}$) and transversal direction ($\varepsilon_{11}$). All samples reveal linear respond thus indicating purely elastic mode of deformation. The fracture strength and maximum strain are 1500 ±50 MPa and 1.60±0.05 %, respectively. Furthermore one can conclude that preloading has no effect on deformation behaviour of $Zr_{64.13}Cu_{15.75}Ni_{10.12}Al_{10}$ BMGs.

***Table I*** *The extent of rolling, Young moduli $E_{11}$, $E_{22}$ and corresponding Poisson ratio $\nu$ for S2 BMGs.*

| *Sample* | *Rolling* [%] | $E_{11}$ [GPa] | $E_{22}$ [GPa] | ν [-] |
|---|---|---|---|---|
| S2_4 | 20 | 93±0.1 | 268±0.5 | 0.347±0.001 |
| S2_6 | 40 | 90±0.1 | 256±0.2 | 0.353±0.001 |
| S2_8 | 60 | 93±0.1 | 260±0.5 | 0.356±0.001 |
| S2_10 | 80 | 91±0.2 | 258±1.2 | 0.354±0.002 |

Fitting the stress-strain curves to the linear function we obtained corresponding Young moduli and Poisson ratio. Table I list the results of quantitative analysis of stress-strain curves presented in Fig.1. Obtained data confirm previous statement that pre-rolling of $Zr_{64.13}Cu_{15.75}Ni_{10.12}Al_{10}$ BMGs has no influence on its tensile deformation. Figure 2 shows comparison of stress-strain curves (observed in tensile direction, $\varepsilon_{11}$) as obtained by conventional measurement using test-rig and in-situ XRD. Slight deviation from linearity, in case of test-rig, maybe due to some artefacts originating from device. It is worth to note that increasing extent of pre-rolling results in sample having smaller cross section which in turn limits the maximum load and consequently implies shorter time for getting whole deformation curve (density of points per curve decreases with increasing the extent of pre-rolling). Comparing curves in Fig.3 suggests that degree of deviation from linearity decreases as the total time (density of points) decreases.

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