Shear bands in Zr-Cu-based metallic glasses: New insight

V. Nekouie[1a], A. Roy[1] and V.V. Silberschmidt[2]

[1]Wolfson School of Mechanical and Manufacturing Engineering,

Loughborough University, Leicestershire, UK

[a]V.Nekouie2@lboro.ac.uk

Introduction

Bulk metallic glasses (BMGs) are relatively new materials, considered for use in various high-technology applications thanks to their unique properties. These properties make them ideal candidate for such applications as in MEMS (micro-electromechanical system) devices, miniaturised biomedical implants and micro-robotics devices. BMGs have received much scientific and technological attention due to their prominent mechanical properties such as a high ratio of elastic limit to the Young's modulus and higher fracture toughness, when compared to their crystalline counterparts of similar composition. On average, specific strength of metallic glasses is more than twice of their crystalline counterparts. Metallic glasses also absorb less energy in stress-induced deformation compared with crystalline materials. This is typically attributed to the absence of a long-range order in their atomic structure and lack of defects such as dislocations, which control ductility in traditional metallic materials. Typically, inorganic glasses are brittle at room temperature, exhibiting a smooth fracture surface as a result of mode-I brittle fracture. BMGs have nearly no plasticity in the macro-scale under tensile and compressive deformations and their mechanical behaviour is very sensitive to internal and surface flaws such as microcracks and voids. The cause of this limited macroscopic plasticity in BMGs is the absence of grain structure and an extreme localisation of plastic flow into narrow shear bands that initiate strain-softening [1]. Interestingly, some small-scale experiments demonstrate that high deformability can be obtained in sub-micron and nano-sized metallic-glass specimens [2].

In this study, indentation in metallic glass was carried out to study its plasticity mechanisms through the evolution of localised shear bands that drive material deformation in the sub-micron scale. Shear bands typically form beneath the indenter inside the material volume, making it impossible to study them in detail. Here, a wedge-indentation technique [3] was proposed to characterise the evolution of shear bands in BMG specimens beneath the indenter, by the application of incremental loading to the specimen. Fig. 1(a) shows a special fixture used to attach the indenter to the testing machine (Fig. 1(b)). The schematic of the experiment is shown in Fig. 1(c).

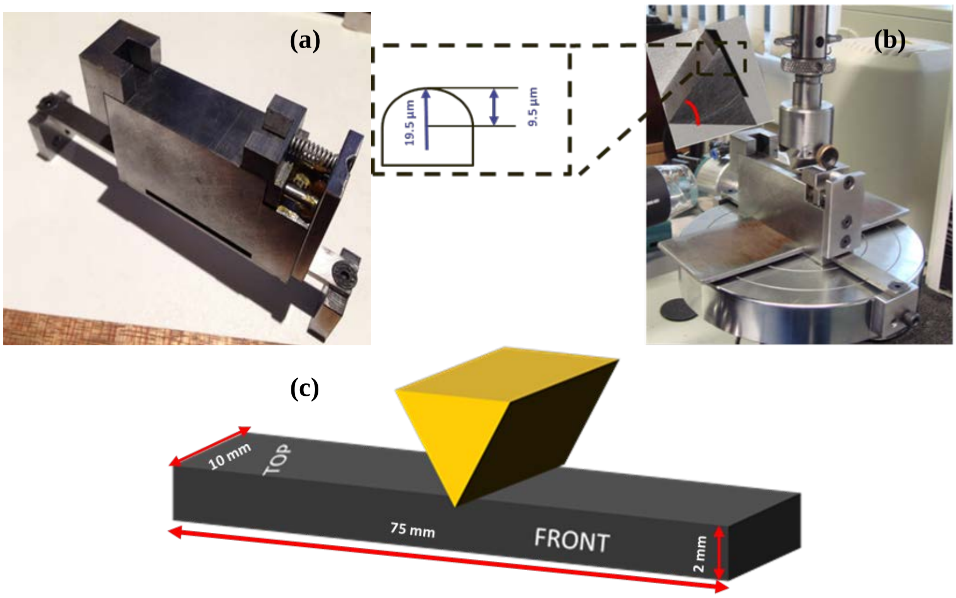

Fig. 1 (a) Designed fixture; (b) experimental setup for wedge indentation (Inset image: wedge indenter and its dimensions) (c) Schematic of wedge-indentation experiment [3]

A surface-decoration technique was employed to track formation and propagation of shear bands during the indentation experiments. Specialised surface-decoration methods are needed to visualise nanometre-scale features at higher magnifications. Focused Ion Beam (FIB) and Focused Electron Beam (FEB) were used to create features with a size less than 100 nm on the specimen's surface. Fig. 2 shows microlines milled with length of 20 µm, width of 0.2 µm and spacing of 1 µm. SEM images of 5000x magnification with a 128 µm horizontal field width (HFW) for DIC studies were taken before and after each incremental loading step to analyse deformation in the material. This study demonstrates the key underlying mechanisms that drive deformation in metallic glasses.

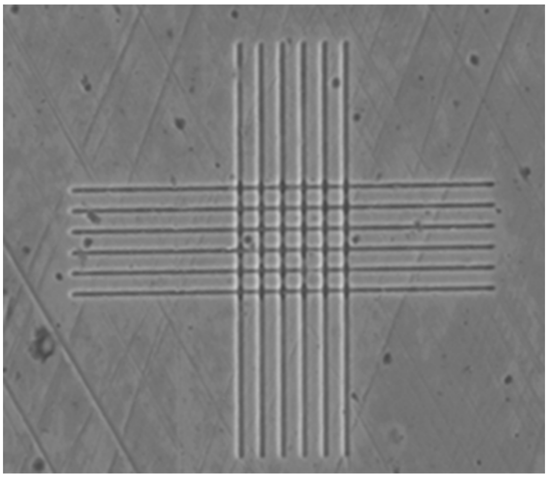

Fig. 2. 6x6 gridline created using Focused Ion Beam on BMG in surface-decoration process

References

[1] W.H. Wang: *The elastic properties, elastic models and elastic perspectives of metallic glasses*, Progress in Mater. Sci. Vol. 57 (2012), p. 487-656.

[2] A.L. Greer, Y.Q. Cheng and E. Ma: *Shear bands in metallic glasses*, Mater. Sci. Eng., Vol. 74 (2013) p 71-132.

[3] V. Nekouie, G. Abeygunawardane-Arachchige, U. Kühn, A.Roy and V.V. Silberschmidt: *Indentation-induced deformation localisation in Zr–Cu-based metallic glass, J. of Alloys Compd., vol. 615 (2013), p. 93-97.*