Mechanical behaviour of $Zr_{41}Ti_{14}Cu_{12.5}Ni_{10}Be_{22.5}$ bulk metallic glass

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1. Introduction

Bulk metallic glasses (BMGs) are promising engineering materials due to their superior mechanical, physical and chemical properties. However, BMGs usually exhibit very poor macroscopic plasticity at room temperature because of their fundamentally different deformation mechanisms compared with poly-crystalline metals. Therefore, understanding the initiation, propagation and branching of shear bands is of benefit to the improvement of the plasticity of BMGs. The indentation test is considered to be an attractive method to investigate the deformation behaviour of BMGs. By using this method, the initiation and evolution morphologies of shear bands beneath the Vickers indenter can be systematically studied in BMGs. In the current work, the morphological feature of the deformation on the subsurface beneath the Vickers indenter was investigated in a Zr-based bulk metallic glass, and the size of the deformation zone and the inter-band spacing as a function of the applied loads were quantitatively analysed and discussed on the basis of current theoretical models.

2. Materials and experimental procedures

- Materials
  - ✓ Composition: $Zr_{41}Ti_{14}Cu_{12.5}Ni_{10}Be_{22.5}$
  - ✓ Preparation: arc melting and water-cooled coper mould casting
  - ✓ Thermodynamic parameters: T_g=623K, T_x=703K
- Experimental procedures
  - ✓ Interface and top surface were polished to mirror finish
  - ✓ Indenter: Vickers
  - ✓ Applied load: 9.8, 49, 196N
  - ✓ Holding time: 30s
  - ✓ Using SEM to observe shear band on the interface

3. Results and discussions

- Morphology of deformation beneath the Vickers indentation

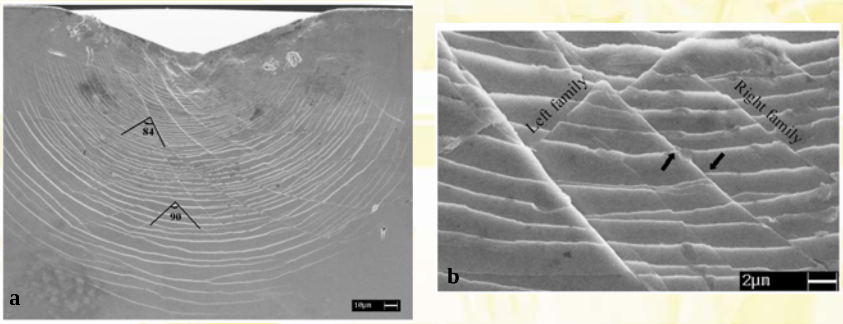


Fig1. (a) A full view of a specimen subjected to an indentation load of 196N. (b) A higher magnification image obtained from within the deformed region of (a).

- ✓ Plastic deformation is accommodated by primary and secondary shear bands
- ✓ Radial shear bands did not initiate simultaneously : left family prior to right family
- ✓ The largest relative displacement along radial shear bands reaches more than 2 μm
- ✓ The included angle between two families of shear band depending on the distance from indenter tip implies the deformation of the BMG exhibits pressure sensitivity

- Space of shear bands

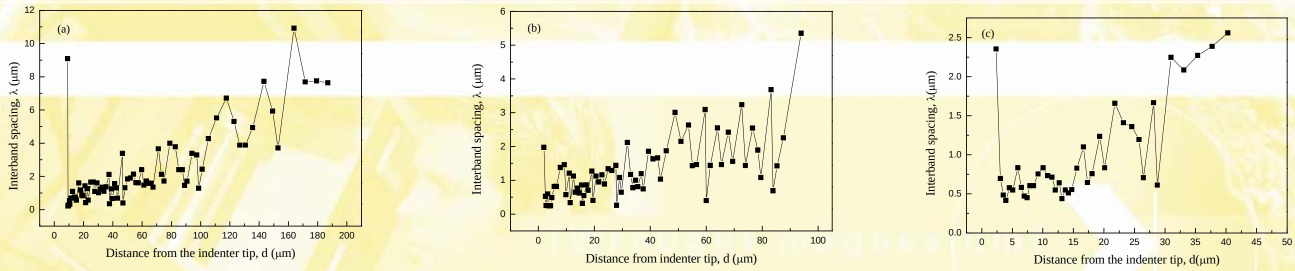
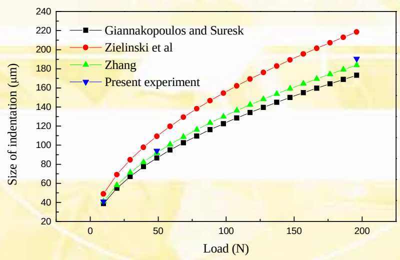


Fig.2. Variation of the inter-band spacing as a function of distance from the indenter tip for different load. (a) load=196N, (b) load=49N and (c) load=9.8N.

- ✓ There is a nearly linear increase in spacing with depth below the indenter
- ✓ The shear band spacing is largely independent of load; the main effect of larger load is only a greater deformation zone

- Deformation zone size



Models predicting the deformation zone size:

Giannakopoulos $$\delta = \sqrt{\frac{0.3P}{\sigma_y}}$$

Zielinski $$\delta = \sqrt{\frac{3P}{2\pi\sigma_y}}$$

Zhang $$\delta = \sqrt{\frac{P}{\pi H}}\left\{\frac{E}{6(1-\nu)\sigma_y}\tan\beta + \frac{2}{3}\frac{1-2\nu}{1-\nu}\right\}^{\frac{1}{3}}$$

δ: hemispherical plastic zone size
σ_y: yield strength in compression
P: load
E: Young's modulus
ν: Poisson's ratio
H: Meyer hardness
β = 19.7° (for Vickers indenter).

Fig.3. Comparison of the experimentally measured plastic zone size with the prediction of some models.

4. Conclusion

A bonded interface technique was employed to observe the shear band evolution beneath Vickers indenter ranging load from 9.8N to 196N. The results show the plastic deformation in as-cast $Zr_{41}Ti_{14}Cu_{12.5}Ni_{10}Be_{22.5}$ bulk metal glass is accommodated by the semicircular shear bands (primary) and radial shear bands (secondary). The size of the deformation zone measured in the present work is in good agreement with prediction from the expanding cavity model. The inter-band spacing between the semicircular shear bands shows increases with increasing distance from the indentor tip under each load. The inter-band spacing of the shear bands obtained under the three loads is identical at the positions with the same distance from tip, which implies that it is independent on applied load. The theoretical model by Zhang et al predicted the deformation zone size more precisely than other models.

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