Observation of shear band in bulk metallic glass by in situ straining in TEM

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In situ straining experiments have long provided a means of investigating deformation mechanisms in metals and alloys because the behavior of crack propagation determines the fracture toughness. Most metallic glasses often exhibit a catastrophic fracture phenomenon against external loads which is closely related to the reliability of the material in practical application. However the knowledge on the deformation mechanism in metallic glasses is still poor and has attracted a lot of attention from both theoretical and experimental sides. In this study, in situ straining TEM experiment has been performed to study the propagation of the shear bands in $Ti_{40}Zr_{29}Cu_9Ni_8Be_{14}$ bulk metallic glass. In the previous study, it has been reported that the compressive plasticity of as-cast $Ti_{40}Zr_{29}Cu_9Ni_8Be_{14}$ metallic glass is significantly enhanced compared with those of other bulk metallic glasses. [1] Such an enhanced plasticity has been attributed to the formation of larger number of shear bands before compressive fracture. Although deformation constraints are reduced in the thin foil sample, and the stress mode during in-situ straining is tensile mode, the opportunity to observe the real-time motion of amorphous matrix during straining, in conjunction with detailed post-mortem characterization, is a powerful tool for deformation studies of metallic glasses.

The substrate was produced in the form of rectangular plate (11.5 × 2.5 mm) with the thickness of 270 ㎛. The specimen was prepared by an ion beam milling method (Baltec, RES 101). The sample was carefully prepared to make a thin area in the center of the specimen without ion beam damage. In situ straining was performed in a JEOL ARM1300S, operating at 1250 KV, using a Gatan model 672 single tilt heating-straining holder. The strain interval was 1.0 ㎛/s and the high resolution image was recorded using GIF MS-CCD.

Fig. 1 shows a bright-field TEM image of the specimen taken during in situ straining experiment. After straining up to 120 ㎛, crack was observed (Fig. 1(a)) to propagate from the hole. Fig. 1(b) is the magnified image of the inset in Fig. (a). A localized deformation was observed mainly in the vicinity and ahead of the cracks, where shear bands were formed. Several very sharp lines were observed inside the broad white band. Because of the reduction in density and thickness of the material in the shear band, shear band region appears to be brighter than undeformed amorphous matrix in bright field image. HREM image (Fig. 1(c)) also shows that the very sharp line with the width of 2 nm exhibits brighter contrast.

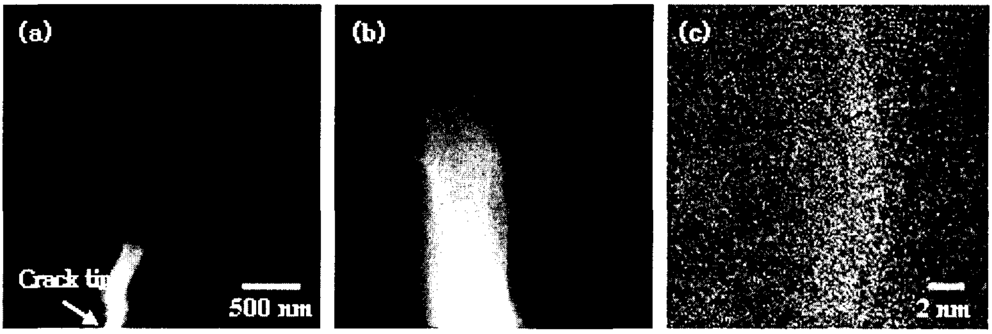

Fig. 1.(a) Bright filed image of a crack; (b) magnified image of the inset in (a); and (c) HREM image of the shear band in $Ti_{40}Zr_{29}Cu_9Ni_8Be_{14}$ alloy.

During the in situ tensile test, the failure of the specimens occurred in the direction normal to the applied stress. This crack propagation across the specimen indicates that the strain is uniaxial. Fig. 2 is an optical micrograph obtained from the failed specimen.

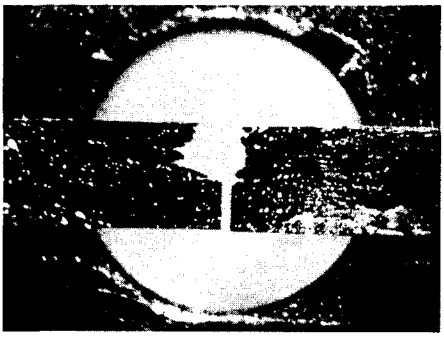

Fig. 2. OM micrograph image which shows the failed specimen after straining experiment.

Reference

[1] H. J. Chang, W. T. Kim and D. H. Kim, Materials Science Forum Vol. 475-479. (2004) 3409.