Spatially Resolved Measurement of Phase Transformation in a Bulk Metallic Glass Alloy

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Introduction

Bulk metallic glasses have good mechanical formability in their viscous state. This desirable property offers great advantages for fabricating near-net-shape structural components. Recent tensile experiments on $Zr_{52.5}Cu_{17.9}Ni_{14.6}Al_{10}Ti_5$ however found fracture surfaces in specimens that had been deformed at elevated temperature. Our experiment was initiated to determine if a bulk amorphous to nanocrystalline phase transformation had occurred and if it was related to deformation.

Methods and Materials

Spatially resolved x-ray powder diffraction was performed on three specimens: (1) as cast (undeformed), (2) deformed at 683K, and (3) deformed at 713K. The x-ray beam size was approximately 0.1x0.3 mm^2. Although powder diffraction with small highly collimated x-ray beams is often complicated by insufficient particle averaging, with amorphous and nanocrystalline materials particle-averaging is acceptable down to very small beam sizes. The specimens were standard tensile specimens with smoothly varying cross sections, hence the amount of local deformation varied along the pulled samples.

Results

Some typical powder results from the three samples are shown in Fig. 1. For the 683K specimen an occasional sharp crystalline Debye ring was observed, but the crystalline ring did not appear to be correlated to the distance from the fracture tip. The typical crystalline size was estimated to be about 2.3 nm. In the case of the 713K specimen, the sample was clearly more crystalline (Fig. 1c), but the crystalline signature again was not correlated to the deformation. For a baseline, measurements were also made from the as-cast sample. This sample showed a clearly amorphous pattern (Fig. 1a) over the entire sample with an occasional sharp crystalline Debye ring that is believed to be due to a thin oxide layer or some surface contaminant.

After it was determined that the diffraction pattern was uniform over the samples, the CCD detector was replaced by an analyzer crystal to obtain high-resolution measurements of the Debye rings of the 713K specimen. The crystalline phase was identified as primarily Zr_2Ni. Crystalline grains were estimated to be at least as large as 9 nm. This observation is consistent with earlier studies of crystallization in this alloy.

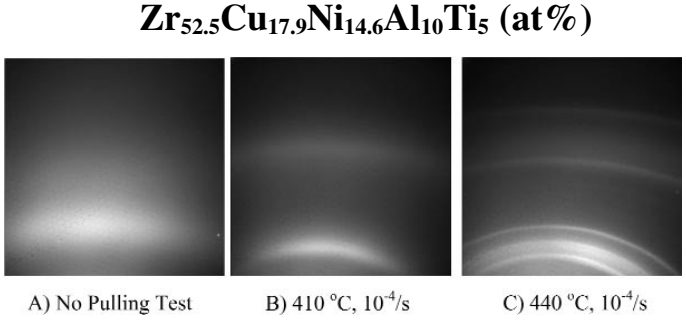

FIG. 1. (A) Powder diffraction pattern from the as-cast bulk amorphou alloy (BAM) specimen. This pattern shows a classic amorphous signature. (B) Powder diffraction from the specimen pulled at 410°C. Here the amorphous pattern shows sharpening characteristic of a very small nanocrystalline phase transformation. The estimated grain size is ~2 nm. (C) At 440°C the crystalline phase can be tentative identified as Zr_2Ni. The grain size is ~9 nm.

Discussion

From the measurements it appears that the samples have undergone a partial amorphous-to-crystalline transformation primarily as a function of temperature. The amount of strain does not appear to have a major influence on this process. These observations are consistent with the fact that tensile testing at 683K shows better ductility than at 713K.

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Reference

[1] T.G. Nieh, J. Wadsworth, C.T. Liu, G.E. Ice and K.-S. Chung, "Extended Plasticity in the Supercooled Liquid Region of Bulk Metallic Glasses," Mat. Trans. JPN (submitted).