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Low Temperature Failure of $Al_{90}Fe_7Ta_3$ Amorphous Alloys

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The fractographic analysis was used for the interpretation of ultra-low temperature dependences of yield or fracture stress. Analysis of fracture morphology revealed that dominantly chevron morphology is present and that the failure of this amorphous material initiates at low temperatures at geometrical imperfections of ribbons and these failures are often presented as a premature failure.

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1. Introduction

The Al–Fe based system is important for future development of high-strength type engineering materials as well as of a new type of elevated temperature strength material. In recent years amorphous and nanostructured Al-based alloys have the increasing potential for engineering applications [1, 2].

2. Experimental

The 33 μm thick and 3–5 mm wide ribbons $Al_{90}Fe_7Ta_3$ (at.%) were prepared by rapid melt quenching on a spinning metallic disc [3]. The amorphous structure of all samples was confirmed by X-ray diffraction. Ribbons were fractured by a tensile test using the deformation rate of 2.6×10^{-4} s^{-1} in the interval 0.5–300 K. The testing temperatures of 77 and 4.2 K were obtained using the liquid nitrogen and liquid helium, respectively, and temperatures below 4.2 K by pumping of ^{3}He vapour in cryostat [4]. A scanning electron microscope was used for fractographic observations.

3. Results and discussion

The measured fracture stress σ_f in the low temperature region of 0.5–4.2 K as well as in the interval up to the room temperature are shown in Fig. 1a and b, respectively. The used symbols represent dominant micromechanisms of failure. The shear failure manifestations, mainly vein morphology, are assigned by the closed symbols, whereas the open symbols represent the situations when the chevron pattern morphology is dominant.

Generally, the deformation of amorphous alloys is localized into the narrow shear bands. Following fracture is catastrophic due to the softening of material in shear bands. The ductile shear failure by the process of meniscus instability inside catastrophic shear band is realized in the plane of maximal shear stress. On the other hand, the chevron patterns are present at fracture surface in the plane of maximal tensile stress.

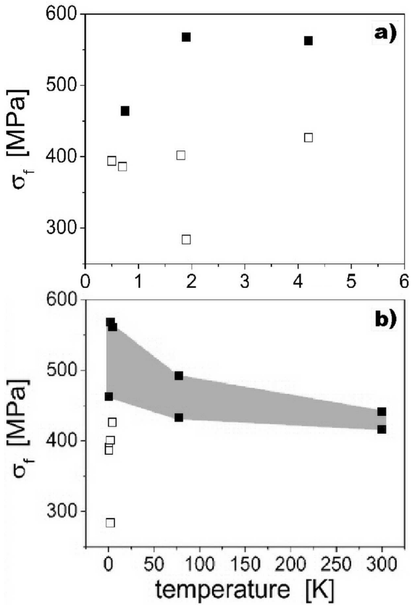

Fig. 1. The measured fracture stress in low temperature region 0.5–4.2 K (a) and in the interval up to the room temperature (b). Symbol □ marks premature fracture and symbol ■ marks shear failure.

Figure 2 demonstrates that the vein pattern manifestations present at shear fracture in whole examined temperature interval are similar and typical for this morphology type [3, 5, 6].

At samples failing at low temperatures, the chevron patterns are frequently observed (Fig. 3). By decreasing of the testing temperature, the critical size of the initiation centres of chevron-like failure decreases. The smaller imperfections of amorphous structure become active and cause the initiation of the failure at the stress below the yield stress of material.

The imperfections can be of the geometrical or structural (as clusters in amorphous matrix of Al-based al-

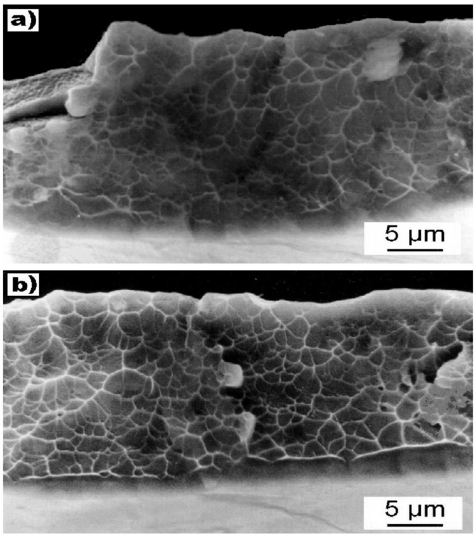

Fig. 2. Ductile fracture surface morphology at 0.75 K — shear failure (a) and fracture morphology at 77 K with shear band near fracture surface (b).

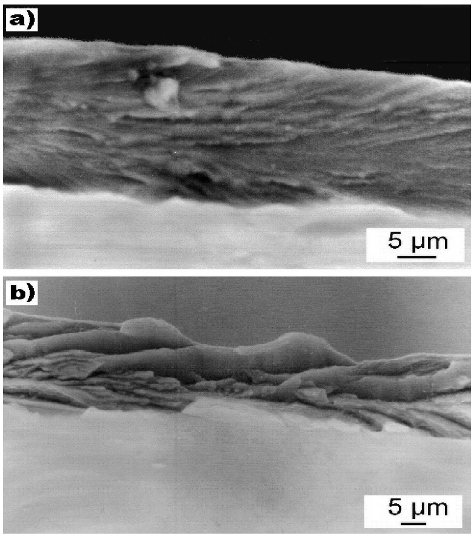

Fig. 3. Flat chevron morphology on the fracture surface at the temperature of 0.5 K (a) and rough chevrons at failure temperature of 4.2 K (b).

loys) origin [1, 7, 5]. The dominant geometrical imperfections on the ribbon surface are inherent properties of the metallic glass prepared by melt spinning method. Its origin is connected with the expansion of gas at the cooling wheel–melt interface [3]. The structural relaxation can also cause the brittleness of amorphous alloys [5, 6, 8–10]. This failure is the premature fracture type at low failure stress [11], as Fig. 1 demonstrates using open symbols.

4. Conclusion

Fracture analysis of amorphous alloys $Al_{90}Fe_7Ta_3$ failing in the temperature interval 0.5–300 K has shown that the fracture stress increases with the temperature decrease. Shear ductile failure manifestations were observed at testing temperatures above 0.75 K. Below the temperatures 4.2 K, the severe initiation centres for chevron-like fracture activates. This failure can be assigned as a premature fracture and the measured fracture stress does not represent the yield stress of intrinsic material.

Acknowledgments

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