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Microindentation as a perspective method for determination of mechanical properties of ribbon metallic glasses

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Abstract: Conditions of gauging of true microhardness of thin ribbons metallic glasses (MG) with the count of their depth are established. For the first time the method of a indentation was approved for an assessment of crack resistance of MG. The behavior of parameterK_{Ic} is found in a interval of temperature of viscous-brittle transition down to the beginning of volumetric crystallization of MG. The estimation method of temperature of viscous - brittle transition is offered at the microindentation of annealing ribbon on an elastic substrate.

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1 Introduction

The microindentation is spread, available and prime method of reliable definition of mechanical characteristics of solid materials, not becoming elimination at investigation of thin ribbons amorphous metallic alloys.

However, it is necessary to take into account small depth of samples, them prehistory, parameters of obtaining, a singularity of an amorphous state at receiving the information by this method. All these facts impose limitation on procedure of an indentation.

2 Experimental results and discussion

2.1 Microhardness

Microindentation by Vickers's pyramid is used widely at definition of microhardness of thin hardening coatings in particular, amorphous alloys. However during his application there are difficulties of comparison of outcomes for the coatings having different depth or marked on different materials, because of a plastic deformation of the substrate and forcing through of a coating. In this case the correcting of a microhardness testing is necessary.

We used samples of MG on a base of cobalt and iron which depth was varied 25-35 μm. Microhardness was defined on a standard technique [1] on instrument PMT-3 at different loads on indentor $P=$ 10-100 g.

It was marked that magnitude Hv does not depend on p at the indentation by load $P<$ 70 g (depth of penetration 1/12 - 1/20 from depth of ribbon MG). This fact allows to consider that measurements give

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true values of microhardness. Limitation in method is load $P \geqslant 70$ g as at its reaching Hv are sharply reduced on 1-2 GPa (Fig. 1). Besides at loads $P \geqslant 70$ g the assessment of microhardness is complicated: a) numerous macro-and microcracks (on annealed samples) or zones of a plastic deformation- shear bands (on samples without annealing) generating at indentation and strongly deforming geometry of an impression; b) the substrate affect on the results investigations. Thus, outcomes of a local loading of examined ribbon of MG are reliable, if penetration depth of indentor does not exceed 2.5 μm.

2.2 Crack resistance

K_{Ic} is one of the most important engineering measure for a forecast of mechanical behavior-quantitative assessment of a fracture toughness high-tensile and low-plastic structural and instrumental materials (for example, glasses, ceramics, hard-facing alloys, silicon carbide, etc.).

Different methods of assessment K_{Ic} are known-three and a four-dotted flexure of a sample with notch, an eccentric tension, a double torsion and others[2], demanding laborious stages of mechanical treatment, presence of an special testing equipment, a numerous amount of samples of the composite form (with indented layers, apertures, cuts).

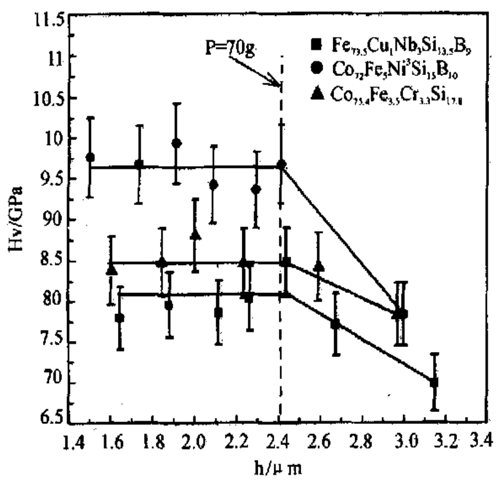

Fig. 1 Dependence of microhardness MG from depth of indentor introduction

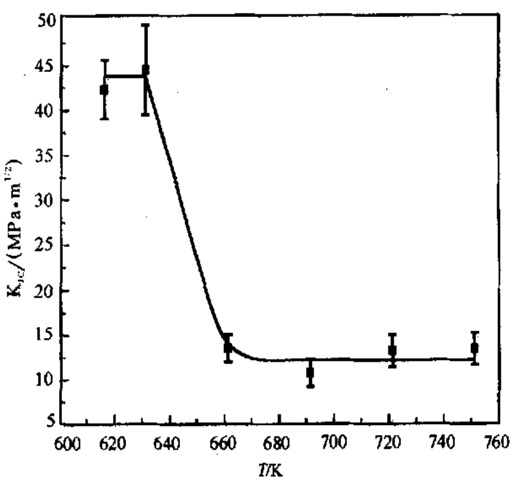

Fig. 2 Behavior K_{Ic} at heat treatment of MG (Co-Fe-Cr-Si)

The routine methods of crack resistance definition are unsuitable for samples of small sizes and small depth, such as thin ribbon MG. Recently methods, founded on a local loading of a material, have received a wide spread occurrence[3, 4]. The semiempirical ratios connecting K_{Ic} of a sample with critical load for a microcrack nucleation stage and with the dimensions of a crack for a stage of its propagation which at use of crack resistance microtestings of brittle materials[5-7], are exist.

We studied an amorphous alloys of the composition (at. %): 75.4%Co + 3.5%Fe + 3.3%Cr + 17.8%Si in the form of a ribbon. Thick is 30 μm. We applied the semiempirical formula for account K_{Ic}[4]: $K_{Ic} = A(E/Hv)^{1/2} P/C^{3/2}$, where $A = 0.016$—a constant of proportionality, E—an Young modulus, Hv—Vickers's microhardness, P— critical load of appearance of radial crack, C —ength of radial crack.

It was found by the method of indentation, that the fracture toughness of MG changes nonmonotone at low annealing temperatures. It is connected to variation of firmness of deformation band depending on temperature of heat treatment[8]. It was obtained the sharp quadruple fall of crack resistance (Fig. 2) in the temperature interval of viscous-brittle transition. The magnitude K_{Ic} escapes on a saturation, accepting approximately equal values at the next temperatures of isothermal annealing. The plasticity of MG is circumzero. The base contribution to the mechanism of dissipation of energy during destruction introduces energy of appearance of main cracks (the contribution of shear bands is minimal), weakly temperature-dependent.

2.3 Temperature of viscous-brittle transition

Measurement of probability of cracks formation (W) depending on load (P) during indentation of annealed MG on substrate [9] allows to define temperature of viscous-brittle transition (T_f) of samples. If cracks arise with probability more than 0,5 since the certain critical temperature (T_{cr}) at maximum load on indentor $P = 200$g then $T_{cr} = T_f$(condition: $T < T_{cr}$ —cracks are not formed, $T_{cr} > T$ - $W \to 1$). It was established, that more elastic, softer used substrate at indentation of MG, then the concurrence of T_{cr} is more exact to true temperature of viscous - brittle transition which is received by an independent U-method.

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