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NUCLEATION OF Al NANOCRYSTALS IN THE AMORPHOUS $Al_{87}Ni_8Y_5$ ALLOY AT CONSTANT RATE HEATING

The process of formation of a nanocomposite structure in the amorphous $Al_{87}Ni_8Y_5$ alloy at constant heating rate of 5 K/min was studied by X-ray diffraction and measurements of electrical resistance and microhardness changes. By comparison of the experimentally measured changes of the average sizes of nanocrystals and their volume fraction, it was established that the nucleation rate of Al nanocrystals increased with temperature up to about $1.6 \cdot 10^{22}$ $m^{-3} \cdot s^{-1}$ in the range of 488–491 K and then decreased by about an order of magnitude at the final stage of nanocrystallization (570 K). It was shown that the observed behavior of the nucleation rate can be satisfactory described within the classical model of homogeneous nucleation accounting lowering of the thermodynamic driving force of transformation due to the enrichment of the residual amorphous matrix with the alloying elements. It was found that preliminary heating of the samples up to temperatures corresponding to the nucleation rate maximum resulted in lowering of the onset crystallization temperature by about 9 K and enhancement of microhardness of the nanocomposite structure from 5210 to 5700 MPa that was caused by increment of the volume density of Al nanocrystals from $1.87 \cdot 10^{23}$ to $2.14 \cdot 10^{23}$ m^{-3}.

Keywords: amorphous alloys, nanocrystallization, rate of nucleation, diffusion-limited growth, thermodynamic driving force, microhardness

Fig. 1. Variations of the derivative of electrical resistance at heating with the rate of 5 K/min of the amorphous $Al_{87}Ni_8Y_5$ ribbons in the as-cast state (—) and after preliminary heating up to 484 K (– – –) and to 518 K (····). The numbered arrows mark the onset crystallization temperatures of the corresponding samples. Inset: X-ray diffraction patterns of the ribbons in the as-cast state (*1*) and after heating up to 570 K (*2*)

Fig. 2. Changes of the average grain size of Al nanocrystals (●) and the transformed volume fraction (○) in the amorphous $Al_{87}Ni_8Y_5$ alloy during heating with a rate of 5 K/min. The solid line is the $L(T)$ dependence calculated from Eq. (3)

Fig. 3. Changes of the nucleation rate of Al nanocrystals in amorphous $Al_{87}Ni_8Y_5$ alloy during heating with the rate of 5 K/min estimated from the experimental data (○) and calculated from Eq. (4) (– – –)

Fig. 4. Effect of preliminary heating temperature T_h on the onset crystallization temperature T_{ons} in the amorphous $Al_{87}Ni_8Y_5$ ribbons

Fig. 5. Variations of microhardness of the amorphous $Al_{87}Ni_8Y_5$ as-cast samples heated up with the rate of 5 K/min to different temperatures (○) and those of the samples subjected to preliminary heating up to various temperatures and succeeding heating up to 570 K (■)