

Influence of yttrium on changes in the structure of amorphous metal alloys of the $\text{Al}_{87}(\text{Y,Gd})_5(\text{Ni,Fe})_8$ system due to short-term annealing

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In this work, the influence of rare earths and transition metals on the kinetics of stable crystallisation for the amorphous metal alloys (AMAs) with the following compositions: $\text{Al}_{87}\text{Gd}_5\text{Ni}_4\text{Fe}_4$ and $\text{Al}_{87}\text{Y}_4\text{Gd}_1\text{Ni}_4\text{Fe}_4$ are shown. Isothermal annealing were performed at certain temperatures with heating rate 20 K/min determined from the DSC curves, which are characteristic of stable growth of crystals of the secondary crystallization stage and equal to 645 and 647 K, respectively. X-ray diffraction analysis showed that after 5 minutes of isothermal annealing, nanocrystalline thermally stable phases of $\text{Al}(\text{X})$, GdFe_2 , AlFe_2Ni were formed, which did not change during the crystallisation process for AMAs systems $\text{Al}_{87}(\text{Y,Gd})_5(\text{Ni, Fe})_8$. Changes in the structure and size of the nanocrystals during the crystallisation process were investigated by transmission electron microscopy and high resolution electron microscopy (TEM/HREM, Jeol JEM 3010). The analysis confirmed that the addition of yttrium significantly changes the crystallisation temperature and phase composition of the crystallised alloys.

The object of the tests were AMAs alloys in the form of ribbons with a thickness and width of 20-25 μm and 3 mm, respectively, which were obtained at the G. V. Kurdyumov Institute for Metal Physics of the National Academy of Sciences of Ukraine (Kyiv) by melt spinning method in a helium atmosphere on a copper drum rotating at a speed of ~ 30 m/s. The melt was prepared from pure metals and binary compounds REAl_3 (RE = Y, Gd). The purity of the starting metals was as follows: Al (99.999 wt.%), Ni (99.99 wt.%), Y (99.96 wt.%), Gd (99.96 wt.%) and Fe (99.99 wt. %).

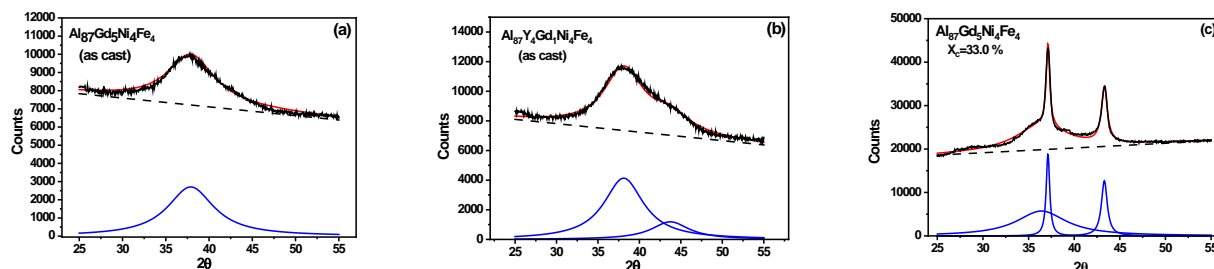


Figure 1. Profiles of the main maxima of amorphous alloys of the $\text{Al}_{87}(\text{Y,Gd})_5(\text{Ni,Fe})_8$ system: (a) as cast $\text{Al}_{87}\text{Gd}_5\text{Ni}_4\text{Fe}_4$, (b) as cast $\text{Al}_{87}\text{Y}_4\text{Gd}_1\text{Ni}_4\text{Fe}_4$, (c) isothermally annealed for 5 min at $T=645$ K $\text{Al}_{87}\text{Gd}_5\text{Ni}_4\text{Fe}_4$

The main maximum of AMA $\text{Al}_{87}\text{Gd}_5\text{Ni}_4\text{Fe}_4$ of the intensity curve has a symmetrical shape and can be approximated by a single Lorentz function (Fig. 1a), which shows the profile of the main maximum. The average interatomic distance in the amorphous alloy equal to 2.91 \AA , and the size of the coherent scattering regions is $L \approx 14$ \AA . Thus, it can be concluded that the replacement of yttrium atoms with gadolinium atoms in the amorphous alloy significantly reduces the degree of structural microhomogeneity.

In Fig. 1b, the main maximum of AMA $\text{Al}_{87}\text{Y}_4\text{Gd}_1\text{Ni}_4\text{Fe}_4$ is presented as a superposition of two submaxima, indicating the formation of a mixture of two amorphous phases of different chemical composition and type of short-range atomic order in the initial amorphous alloy. The average interatomic distance in the amorphous phase (AP)₁ is equal to $R_1 = 2.91$ \AA , which exceeds the sum of the atomic radii of Al ($2R_{\text{Al}} = 2.86$ \AA), indicating the enrichment of the amorphous phase (AP)₁ with atoms of rare earth elements (Y, Gd). The volume fraction of the phase in the amorphous $\text{Al}_{87}\text{Y}_4\text{Gd}_1\text{Ni}_4\text{Fe}_4$ alloy, determined by the ratio of the integrated intensities of the submaxima, reaches almost 80%. However, a significantly smaller value of the interatomic distance ($R_1 = 2.55$ \AA) is observed in the amorphous phase (AP)₂.

In addition, the value of R_1 is less than the sum of the atomic radii of Al and Ni(Fe) ($R_{\text{Al-Ni}} = 2.68$ \AA), indicating the formation of microregions with strong chemical interaction between Al atoms and transition elements (Ni, Fe).