STRUCTURE OF $Al_{87}Ni_8Dy_5$ IN AMORPHOUS AND NANOCRYSTALLINE STATE.

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Introduction

Amorphous aluminum based alloys with transition and rare earth metals attract the attention of researchers because they exhibit the growth of nanocrystalls at heating. It is important that nanocrystalls of Al, growing from amorphous matrix are defects free and have a relatively small size (25 nm) [1, 2]. Such nanocrystalls are suggested to be responsible for the improvement of mechanical properties. For instance their flow limit reaches 1.6 GPa that is by one order larger than in traditional aluminum alloys [3]. Certainly that thermodynamic and kinetic feature determine the nanocrystalls growth characteristics but it is clear that short range order structure of initial amorphous alloy and its change with heating are also main factors, determining the nanocrystalls growth process. We have used the high temperature X-ray diffraction in order to study the structure changes in $Al_{87}Ni_8Dy_5$ amorphous alloy at heating.

Experimental

Materials

Amorphous ribbons of 25 μm thickness and 10 mm width have been obtained by rapid cooling from liquid state on rotating with high speed disk. Cooling rate was equal to 10^6 K/s. Chemical composition was controlled by means of X-ray fluorescence analysis.

Apparatus and Procedures

X-ray diffraction studies of amorphous and nanocrystalline sample have been carried out with using of DRON-3M (Russia) diffractometer attached with high temperature chamber (Bragg-Brentano focusing geometry; Cu-Kα radiation, monochromatized by graphite single crystal). Temperature was measured and controlled by chromel-alumel thermocouple with accuracy about ±1 K. Scattered intensity was recorderd within $2\theta=5\text{-}125^{-o}$ region of scattering angles. Soft ware package Origin-6.0 was used to correct and calculate the the structure functions from diffraction data. Volume fraction of initial nanocrystalls was estimated supposing that scattering from amorphous and nanocrystalline phases are indepependent Nanocrystals density was calculated in assumption that these nanocrystals have the spherical shape.

Results and Discussion

Intensity curve shows the asymmetric peak with shoulder (Fig. 1) at s=29.8 nm^{-1}. Using Erenfest formula $R = \frac{7.73}{s}$ it is shown that mean interatomic distances is close to sum of $R_{Al}+R_{Ni}$=0.268 nm. Therefore the shoulder appearance is caused by the scattering from structure units with Al-Ni interaction. Similar results were obtained for Al-Co-Ce [4] and Al-Ni-Pr systems [5]

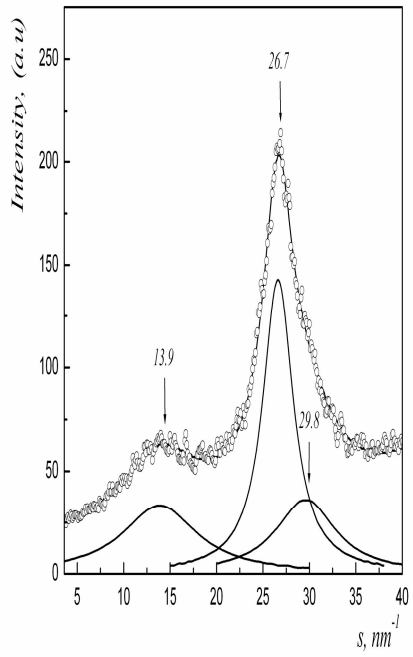

Fig. 1. Intensity curve of $Al_{87}Ni_8Dy_5$ amorphous alloy

Position of principal peak s=26.7 nm^{-1} corresponds to interatomic distance R=0.289 nm, that is close to $2R_{Al}$=0.286 nm, indicating the scattering from structural units, whose topology is similar to short range order of liquid Al.

Important feature of intensity curves is existence of pre-peak at s=13.8 nm^{-1} which is caused by intermetallic short range order with correlation length $L_{cor.}=2\pi/s=0.45$ nm. Most probable that interaction of Al and Dy- atoms is responsible for the intermediate short range order that also is confirmed in [6, 7]. At heating to 418 K an initial nanocrystalls with mean size of 8 nm are formed. Most intensive growth of these nanocrystalls with size from 8 to 15 nm occurs in temperature region 418-463 K (Fig. 2).

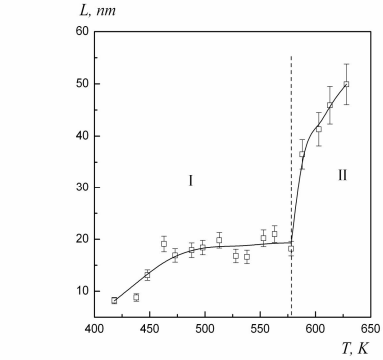

Fig. 2. Temperature change of Al nanocrystalls size: I- the first stage and II- the second stage of crystallization.

Fig. 3 represents the diffraction spectrum for amorphous-nanocrystalline alloy, obtained at 448 K. Beside (111) and (200) peaks of Al, the diffusive maxima at s=25.2 nm^{-1} and 28.3 nm^{-1} are also observed. Obtained result indicates the decomposition of residual amorphous phase into mixture of phases, enriched with Ni and Dy atoms. It should be noted that at heating of alloy from 463 to 578 K., the nucleation processes and growth of Al-nanocrystalls become slower. On other hand the density of nanocrystals in fact is un dependent on temperature and equals ~2.1 10^{23} m^3 while their size varies in the temperature range 418-578 K

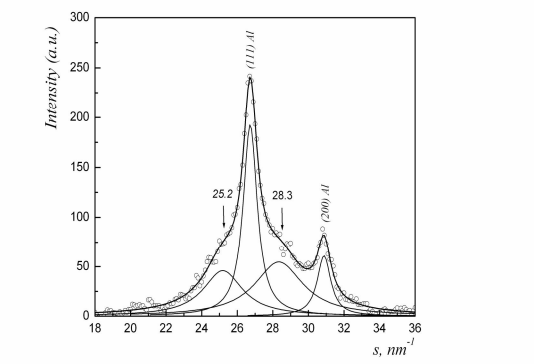

Fig. 3. Diffraction pattern of $Al_{87}Ni_8Dy_5$ alloy at T=448 K

Conclusions.

Structure of $Al_{87}Ni_8Dy_5$ amorphous alloy reveal the significant sensitivity to heating. At low temperatures the short range is like to short range order of liquid Al with tendency to preffered interaction of Al-Ni pairs. Interaction of Al and Dy is responsible for the formation of intermediate range order. Most intensive growth of these nanocrystalls with size from 8 to 15 nm occurs in temperature region 418-463 K

References

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