MATERIALS SCIENCE

DOI https://doi.org/10.30525/978-9934-26-264-7-10

STRUCTURE EVOLUTION IN $AL_{70}SI_{20}NI_{10}$ RAPIDLY-QUENCHED ALLOY

ЕВОЛЮЦІЯ СТРУКТУРИ ШВИДКО-ЗАГАРТОВАНОГО СПЛАВУ $AL_{70}SI_{20}NI_{10}$

Nykyruy Yu. S.
Candidate of Physical and Mathematical Sciences, Associate Professor at the Metal Physics Department Ivan Franko National University of Lviv

Никируй Ю. С.
кандидат фізико-математичних наук, доцент кафедри фізики металів Львівський національний університет імені Івана Франка

Mudry S. I.
Doctor of Physical and Mathematical Sciences, Professor, Head of the Metal Physics Department Ivan Franko National University of Lviv

Мудрий С. І.
доктор фізико-математичних наук, професор, завідувач кафедри фізики металів Львівський національний університет імені Івана Франка

Prunitsa V. V
Postgraduate Student at the Metal Physics Department Ivan Franko National University of Lviv Lviv, Ukraine

Пруніца В. В.
аспірант кафедри фізики металів Львівський національний університет імені Івана Франка м. Львів, Україна

Al-Si-Ni alloys are used in such industrial areas as automotive, aerospace, electronics, etc. With the aim of utilizing a high-strength material with light weight a great effort has been devoted to the production of amorphous Al-rich alloys. It is considered, that rapidly solidified Al–Ni–Si amorphous alloys are a better choice for practical application as materials with high strength, low density, and useful physical properties [1]. It is known the physical properties of a material at an amorphous or nanocrystalline state depend on its structure and phase composition. Controlled change of structure allows obtaining the desired properties of a material. So the investigation of the structure evolution of rapidly-quenched $Al_{70}Ni_{10}Si_{20}$ alloy is presented in this study.

The $Al_{70}Ni_{10}Si_{20}$ alloy was produced by rapid cooling from a melt in the form of a ribbon using the melt-spinning technique. Thickness of the ribbon was about 25 μm and width about 1 cm. The DTA-method was used for alloy investigation under continuous heating. The heating was performed using synchronous thermal analyzer Linseis STA PT 1600 under argon atmosphere at the heating rate of 6 K/min and temperature interval from 293 – 673 K. Isothermal annealing at different exposures and temperatures was used to induce the structure evolution. After annealing the structure changes were investigated using back-scattered X-ray diffraction (XRD) method (Cu-Kα).

The result of DTA of $Al_{70}Ni_{10}Si_{20}$ alloy (Fig. 1) shows three exothermic peaks on the DTA curve: the first peak in the temperature interval of 389 – 406 K; the second one in the temperature interval of 491 – 522 K; and the third one in the temperature interval of 530 – 546 K. The crystallization onset temperature (T_x) was obtained as 389.6 K. Three exothermic peaks may indicate the structure evolution occurs through three-stages and matches the multi-stage model [2, 3].

As-quenched $Al_{70}Si_{20}Ni_{10}$ alloy was investigated using the XRD method and the corresponding curve is presented in Fig. 2 marked 'as-q'. The curve is characterized by a wide halo with small peaks of reflexes and represents an amorphous-nanocrystalline structure. Compared with the similar Al-Si-Ni alloy studied in [4] it can be mentioned that $Al_{65}Si_{25}Ni_{10}$ was obtained in an amorphous state, while $Al_{70}Si_{20}Ni_{10}$ alloy includes some nanocrystalline metastable hexagonal H-phase [5]. However, DTA curves of these alloys are quite similar and represent the process of alloy crystallization.

The samples of the investigated alloy, isothermally annealed at temperatures up to 533 K and exposures up to 1 hour, was studied using the XRD method. The X-ray intensity curves of the alloy annealed at the temperature of 348 K during up to 60 minutes are shown in Fig. 2. This temperature is lower than the crystallization onset temperature (T_x) defined by the DTA (393.6 K). Nevertheless, clear narrow peaks are seen on the intensity curves indicating the H-phase content increasing in an amorphous matrix of the alloy. So, the H-phase was formed in a minor quantity at quenching process and continued to growth in the annealing at 348 K accompanying by the amorphous phase disintegration.

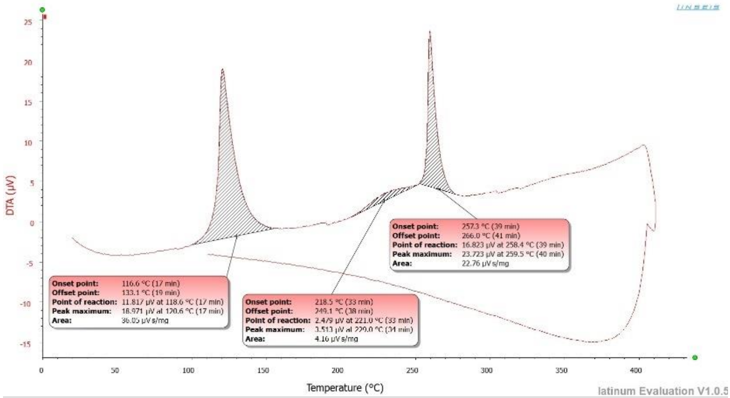

Fig. 1. DTA of the rapidly-quenched $Al_{70}Si_{20}Ni_{10}$ alloy

The hexagonal H-phase was also observed after annealing at 403 K and 463 K (Fig. 3). Its formation can be assigned to the first crystallization peak on the DTA curve.

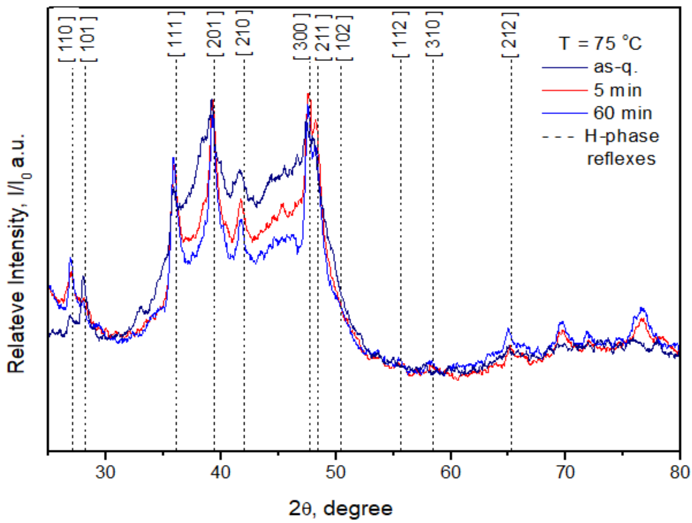

Fig. 2. X-ray intensity curves of the $Al_{70}Si_{20}Ni_{101}$ alloy annealed at 348 K

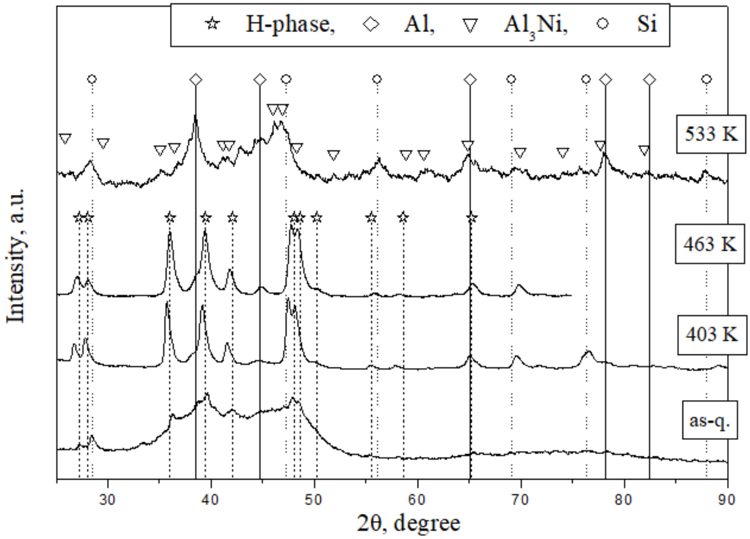

Fig. 3. X-ray intensity curves of $Al_{70}Si_{20}Ni_{10}$ alloy annealed during 1 hour

The intensity curves that correspond to the annealing temperature of 403 K and 463 K are almost similar; the difference is only in peaks intensities. This indicates the H-phase content increased at higher temperature annealing. The H-phase was not observed after annealing at the temperature of 533 K that indicates the H-phase decomposition. Instead, a nanocrystalline phases Al, Si, and Al_3Ni were observed after annealing at this temperature. The temperature of 533 K is close to the third exothermic peak on the DTA curve. Therefore we assume that the third exothermic peak corresponds to the formation of the Al_3Ni intermetallic. From the obtained results, it can be assumed that the second small exothermic peak detected in the temperature range of 491 – 522K is caused by the formation of Al and Si phases.

The heating-induced structure evolution of $Al_{70}Ni_{10}Si_{20}$ rapidly-quenched alloy was studied by means of DTA and XRD methods. The first exothermic DTA peak was obtained at T_x = 389.6 K. The crystallization process is accompanied by the formation of an intermediate metastable hexagonal H-phase. It was shown that the H-phase is stable within the temperature interval of about 403-463 K and at time duration of at least 1 hour. Based on the DTA results, the crystallization temperature of this alloy is 389.6 K, which could be considered as the temperature limit of stability, but as XRD results showed, 1-hour annealing at about 340 K causes partial nanocrystallization. So, the amorphous phase in the $Al_{70}Ni_{10}Si_{20}$ alloy is very unstable

Bibliography:

1. Gögebakan M., Okumus M. Structure and crystallization kinetics of amorphous Al–Ni–Si alloy, *Materials Science-Poland*, 2009, Vol. 27, No. 1,

2. Panda A.K., Kumari S., Chattora I., Svec P., Mitra A., Effect of Fe addition on the crystallization behaviour and Curie temperature of CoCrSiB-based amorphous alloys. *Philosophical Magazine*, 2007, 85:17, 1835, DOI: 10.1080/14786430500098934

3. Minic D.M., Maricic A.M., Dimitrijevic R.Z., Ristic M.M., Structural changes of $Co_{70}Fe_5Si_{10}B_{15}$ amorphous alloy induced during heating. *J. Alloys Comp*. 430, 241 2007 https://doi.org/10.1016/j.jallcom.2006.05.035

4. Nykyruy, Y., Mudry, S., Kulyk, Y. *et al.* Structure and phase transformations of amorphous-nanocrystalline Al-based alloy. *Appl Nanosci* 10, 4385–4393 (2020). https://doi.org/10.1007/s13204-020-01340-y

5. Nykyruy Y., Mudry S., Prunitsa V., Venhryn B., «Structure Investigation of Rapidly Quenched $Al_{65}Si_{25}Ni_{10}$ Amorphous Alloy After Izotermal Annealing,» *2020 IEEE 15th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET)*, 2020, pp. 993-996, doi: 10.1109/TCSET49122.2020.235587.