Acceleration of Processes of Solid Solution Al-4 wt. % Cu Volume Decomposition at Low-Dose Ion Irradiation

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Abstract – The paper presents investigation into the effect of low-dose irradiation with Ar^+ ions (E = 20 keV, j = 200 μA/cm^2, $D = 10^{15}$ ion/cm^2) on decomposition of solid solution of precipitation hardening alloy Al + 4 wt. % Cu. It was established by the methods of microhardness measurement and X-ray diffraction analysis that irradiation with the above low dose (exposure time 1 s) leads to supersaturated solid solution deep decomposition with second-phase particles precipitation. The strong effect of low irradiation doses on the structure and properties of alloy Al-4 wt.% Cu testifies to the presence of a radiation-dynamic contribution to the change in the structure of solids under exposure to accelerated ions.

1. Introduction

In the last period, great attention is being paid to comprehensive experimental and theoretical investigation into radiation-dynamic effects presenting ion irradiation-initiated fast processes and phase transformations taking place in metastable metals and alloys.

Investigation of radiation-dynamic processes in alloys with different types of structural phase and intraphase transformations is a matter of interest. This concerns long- and short-range atomic order formation, new phases formation by diffusion and diffusion-free mechanisms, including the features of the initial stages of transformation, e.g., irradiation-stimulated nucleation and disperse phases precipitation.

2. Description

It was established earlier by the authors of [1] that irradiation of alloy Al-4%Cu samples in the form of foils 100 μm thick quenched in water from 520 °C with a continuous argon ions beam (E = 20 keV, j = 200 μA/cm^2) at doses $D = 2\cdot10^{16}$–10^{18} ion/cm^2 and an aluminium ions scanning beam (E = 30 keV, ion current density in beam j = 180 μA/cm^2, scanning area 5×5 cm^2) with doses 10^{17}–10^{18} ion/cm^2 initiates deep stages of supersaturated solid solution decomposition in the alloy with precipitation of second-phase particles. At that, the temperature of samples heating under irradiation with maximum doses did not exceed 50 °C (at irradiation time from several minutes to several hours).

It is known that, in the course of heating and long-term (several days') exposures at low temperatures, only the zonal stage of ageing takes place in the investigated alloy.

The present paper presents investigation into the effect of low-dose irradiation with Ar^+ ions on supersaturated solid solution Al + 4 wt. % Cu decomposition.

Samples of alloy Al + 4 wt. % Cu in the form of foils 100 μm thick, after quenching in water from 520 °C, were subjected to irradiation with Ar^+ ions (E = 20 keV, j = 200 μA/cm^2, $D = 10^{15}$ ion/cm^2). The sample was fixed on a copper collector with heat-conducting compound to ensure good heat removal. The dose accumulation time was 1 s, the target heating was practically absent.

The Vickers microhardness measurements were carried out with a load of 40 g, the indenter penetration depth was 10 μm.

Microhardness measurements of samples showed that, at low irradiation doses, there is observed a small increase in microhardness, as compared with the initial quenched sample (Fig. 1,a).

In order to establish the degree of decomposition under irradiation and to see to which region of alloy precipitation hardening the obtained microhardness values correspond (before or after the hardness peak), additional experiments were carried out, with the irradiated samples heating in oil at different temperatures and exposure times. Such heating led to drop in

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microhardness, which testifies to the fact that even low-dose irradiation results in deep solid solution decomposition corresponding to the descending branch of the precipitation hardening curve.

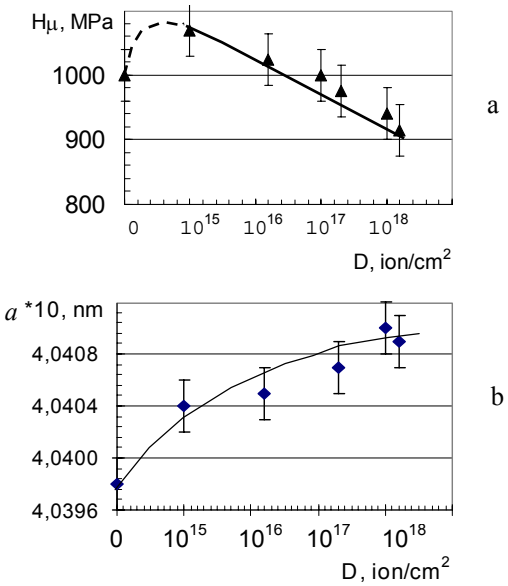

Fig. 1. Changes in microhardness (a) and crystal lattice parameter (б) in solid solution of alloy Al + 4 wt. % Cu in the course of irradiation with Ar^+ ions

Such conclusions are confirmed also with the results of X-ray diffraction analysis, namely, with the increase in the solid solution crystal lattice parameter after irradiation, which points to decomposition with second-phase particles precipitation. So, after irradiation with a dose of $1 \cdot 10^{15}$ ion/cm^2, the crystal lattice parameter values are equal to 0.40404 ± 0.00001 nm, while in the quenched alloy this parameter is 0.40398 ± 0.00001 nm. (Fig. 1,b).

It is seen that, at low irradiation doses, the crystal lattice parameter changes quickly, while with dose increase, the same process slow-down is observed, which corresponds to the decomposition process fade (the curve fade-down view is partly lost due to the logarithmic scale).

At present, direct investigations of the obtained structure are being carried out by the method of high-resolution electron microscopy.

Conclusion

It was thus established that irradiation with Ar^+ ions (20 kev, $j = 200$ μA/cm^2) of supersaturated solid solution Al + 4 wt. % Cu, even at low irradiation dose $D = 1 \cdot 10^{15}$ ion/cm^2, leads to its decomposition with second-phase particles precipitation at room temperature, i.e., the ageing rate increases by several orders of magnitude (as compared with normal thermostimulated ageing at the same temperature).

The strong effect of low irradiation doses on the structure and properties of alloy Al-4 wt. % Cu presents proof to the presence of a radiation-dynamic contribution to change in the structure of solids under exposure to accelerated ions.

References

[1] N. Gushchina, V.V. Ovchinnikov, B. Goloborodsky, A. Mücklich, E. Wieser, *in: Proc. 12th Int. Conf. on radiation physics and chemistry of inorganic materials RFKh-12*, 2003, pp. 192–195.