STIMULATING SUPERPLASTIC DEFORMATION OF Al-Mg-Cu-Si-Mn-Zr ALLOY BY PRELIMINARY PULSED ELECTRON BEAM IRRADIATION

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Preliminary results of the investigation of the superhard X-ray irradiation influence on the superplastic deformation of an aluminium-based alloy are presented. It has been established that the deformation rate of irradiated samples is almost two times higher than that for non-irradiated ones, and the optimum conditions for manifestation of superplasticity are shifted after irradiation towards the region of lower flow stress values.

Introduction

The ability of metals and alloys to be deformed by hundreds and even thousands percents is realized under the conditions of superplasticity. The characteristics of superplasticity (the deformation rate $\dot{\varepsilon}$ and the elongation at the moment of fracture δ) are very sensitive to the extent of defectness of the crystal lattice. It is also known [1] that under the influence of irradiation upon materials they undergo changes of their microstructure and phase composition, and the irradiation of α-uranium by neutrons leads to the rise of the effect of superplasticity in it [2]. For this reason, of great interest are investigations of the influence of different types of radiation on the characteristics of superplasticity of materials. This report presents preliminary results of investigation of the influence of superhard X-ray radiation on the characteristics of superplasticity of a low-doped aluminum alloy of the Avial type.

Subject and methods of the investigations

Prismatic samples with the working area size of 4.5×1.6×10.0 mm^3 were cut out of cold-rolled sheets of the alloy Al - 1% Cu - 1% Mg - 0,6% Si - 0,3% Mn - 0,1% Zr (% of mass) along the rolling direction. Mechanical elongation tests were carried out in the air in the creep regime at a constantly acting flow stress [3]. Characteristic features of the development of the grain and porous structures in the course of superplastic deformation were studied by means of light microscopy, using standard methods of quantitative metallography.

Irradiation of samples was performed at the pulse accelerator "Start" with the following parameters: the beam energy E_n=1 MeV, the current value I_n=10 kA, the current pulse duration τ_p=20 ns. The samples which had been exposed to the irradiation by 10-20 pulses of the bremsstrahlung X-ray radiation were deformed immediately after the irradiation. The results of investigation of the irradiated samples were compared with those for the samples which had not been exposed to irradiation.

Results and discussion

The dependence of the elongation-to-failure δ on the applied flow stress σ for the samples which had not been exposed to the preliminary irradiation is shown in Fig. 1 by curve 1. It can be seen that the maximum value δ = 200% is realized at σ = 4.0 MPa. The deformation temperature was T = 833 K. These conditions are optimal for the manifestation of superplasticity of the non-irradiated samples. In this case, the curves of the creep consist of two stages of flow with the deformation rates which differ from each other by almost an order (Fig. 2). An analysis of the phenomenological parameters has shown that only the flow on the first stage of the creep is superplastic. The true deformation rate on this stage is of 1.4×10^{-4} s^{-1}. The results of the mechanical tests of this alloy were discussed in more detail in [4].

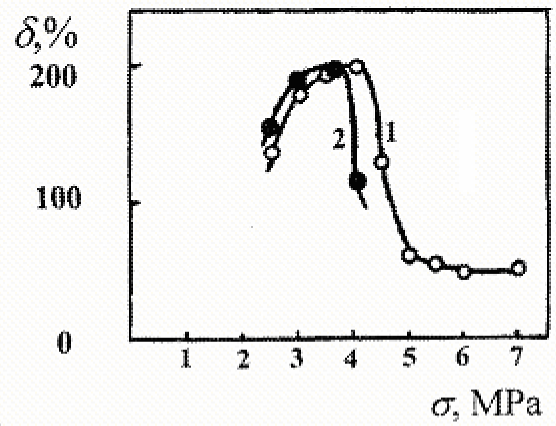

Fig. 1. Dependences of the elongation-to-failure δ on the applied stress σ (1 – for non-irradiated samples, 2 – for irradiated samples).

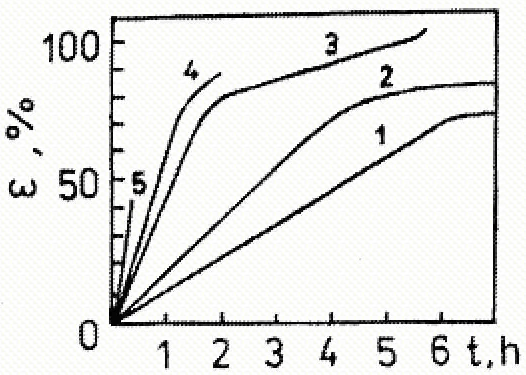

Fig.2. The true curves of creep for non-irradiated samples of the alloy Al-Cu-Mg-Si-Mn-Zr at T= 833 K and σ, MPa : 3.0 (1), 3.5 (2), 4.0 (3), 4.5 (4), 5.0 (5).

The microstructure of the initial samples is shown in Fig. 3, a. It can be seen that it is characterized by a varied graininess. The average grain size is of 40 μm. In the deformed samples grains have the same sizes as in the initial ones (Fig.3, b).

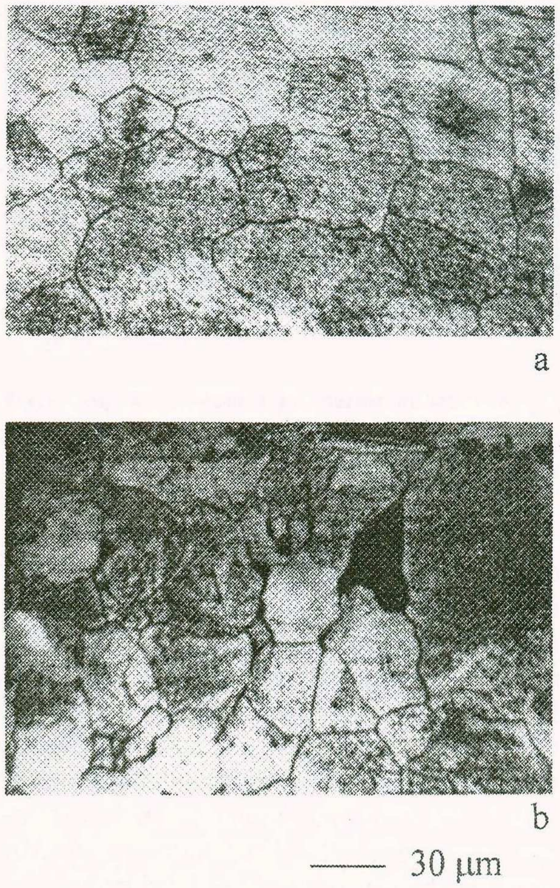

Fig. 3. Microstructure of samples of the alloy Al-Cu-Mg-Si-Mn-Zr: a) an initial sample; b) a sample deformed to fracture at T = 833 K, σ = 4,0 MPa.

Mechanical tests of the irradiated samples were carried out at T = 833 K and σ = 2.5 ÷ 4.5 MPa, i.e. under the conditions which include the optimum conditions for the manifestation of superplasticity by this alloy without any irradiation. The dependence of the elongation-to-failure δ on the applied flow stress σ for the samples exposed to the irradiation is presented in Fig. 1 by curve 2. It has been established that under the same test conditions the deformation rate for the irradiated samples is almost two times higher than the rate for the ones which have not been irradiated. However, it can be seen that the optimal conditions for the superplasticity manifestation shift to the region of lower flow stress values and are realized for the irradiated samples at the stress of 3.5 MPa. In this case, the elongation-to-failure was of 200%. Note, that the superplastic flow rate for the irradiated samples under these conditions was the same as for the non-irradiated ones at σ = 4.0 MPa.

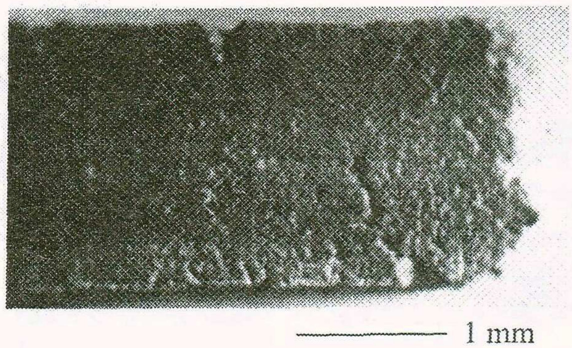

Fig. 4. Fracture surface of a broken sample of the alloy Al-Cu-Mg-Si-Mn-Zr deformed at T = 833 K, σ = 4.0 MPa.

Investigations of the grain structure of the deformed irradiated samples have shown that it is analogous to the structure of the fractured samples which were deformed under the same conditions without irradiation. (see Fig. 3, b). In the both cases, a deformation porosity is intensely developed in the samples [5]. By the moment of fracture its volume reaches up to 7-10%. Thus, during the deformation of samples exposed to the irradiation, no microstructure changes on the mesolevel occur. The type of fracture of the samples can be classified as the quasibrittle one (Fig. 4).

Apparently, the increase of the superplastic deformation rate observed after the irradiation and the decrease of the optimal flow stress could be caused by the increased extent of non-equilibricity of the grain boundaries [5] due to the interaction of the material with the superhard X-ray radiation and by the radiation-induced stimulation of the elementary deformation processes which occur under the conditions of superplastic flow.

References

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СТИМУЛЮЮЧА НАДПЛАСТИЧНА ДЕФОРМАЦІЯ СПЛАВУ Al-Mg-Cu-Si-Mn-Zr ПОПЕРЕДНІМ ОПРОМІНЕННЯМ ІМПУЛЬСНИМ ЕЛЕКТРОННИМ ПУЧКОМ

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Повідомляються попередні результати досліджень впливу наджорсткого рентгенівського випромінювання на надпластичну деформацію сплаву на базі алюмінію. Встановлено, що швидкість деформації опромінених зразків майже вдвічі вища, ніж для неопромінених, а оптимальні умови для прояву надпластичності після опромінення зміщуються в бік нижчих значень напружень потоку.