# MODIFICATION OF THE D16 ALUMINUM ALLOY STRUCTURE BY PULSED RELATIVISTIC ELECTRON BEAM

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The influence of a pulsed intense relativistic electron beam on mesoscopic structural characteristics of D16 aluminium alloy plates is studied. The phenomenological parameters of superplastic flow of alloy D16 plates after irradiation is determined and compared with those before irradiation. The possible causes of improvement in superplastic flow parameters of irradiated material are analyzed.
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## 1 INTRODUCTION

Many methods of metallic material structure modification are known, in particular, explosion processing, temperature hardening, ennobling melting down with an electron beam. High-current electron beam processing of a material allows to simulate all the above-mentioned methods due to the fact that when local beam energy concentrations are higher then $10^7$ J/cm$^2$ the pressure in the target reaches the value of several megabars [1, 2].

Because the maximum of beam energy absorption is reached on the target surface, the surface microexplosion takes place which is accompanied with a shock-plastic wave in the target due to heat exchange. The effects mentioned were the base for studying the structural characteristics and mechanical properties of aluminium alloy plates exposed to pulsed high-current relativistic electron beam.

## 2 MATERIALS AND METHODS OF EXPERIMENT

Initial plates of D16 aluminum alloy (4.8% Cu; 1.5% Mg; 0.8% Mn; impurities of Fe and Si<0.5%; Al based) with the thickness 3 mm were cut out from the massive ingot of the industrial semi-finished product and irradiated from both sides with a high-current pulsed beam of relativistic electrons with the energy density $10^9$ W/cm$^2$ (beam energy $E_b \approx 0.5$ MeV, current $I_b \approx 4$ kA, pulse duration $\tau_p \approx 5\cdot10^{-6}$ sec). The plate was exposed to action of one pulse from each side. Microstructure was analyzed with the help of the light microscopy, using the quantitative metallography standard methods.

Mechanical tests of samples with the length of a working part 10 mm and the width 4 mm were made by tensile straining on air with a constant active flow strain. The time of sample heating up to the test temperature was less then 25 min. The temperature was supported constant with a precision of ±2°. Irradiated and unirradiated samples were tested, results were compared.

## 3 RESULTS AND DISSCUSSION

The initial grained structure of the alloy used is shown in Fig. 1,a. One can see that it is rather coarse-grained, nonuniaxial and heterograined. The structure of the alloy after irradiation is shown in Fig. 1,b. It is ultra-fine-grained and uniaxial. The average size of the grain is 2-3 μm. Such a structure is observed at the whole depth of the plate except a small surface layer. The origin of this structure is caused by a complex effect of electron beam action: temperature, radiation and shocking. Intensive heating leads to melting the surface layer of the plate. The surface of the plate is shown in Fig. 2,a. The same surface in polarized light is shown in Fig. 2,b. Such a view of the surface in polarized light is the result of residual stress presence in the smelted layer of the plate. The structure of the surface layer is rather coarse- grained (near 40 μm). Therefore the surface of irradiated samples was grind off for 0.05-0.1 mm from each side before mechanical testing.

Besides of radiation defects from direct interaction of electrons with the plate, the electron beam braking is accompanied by generation of X-rays, that is an additional cause of formation of radiation defects on whole plate’s depth.

It is known that the effect of dispersion of surface layer precipitates plays a basic role under irradiation with electrons. Substance dissolved as a result of irradiation can precipitate again from the solution in the neighborhood of the parent particle. Although the electron energy (0.5 MeV) is yet insufficient for atom knocking out from the lattice points, nevertheless the beam intensity leading to melting the plate surface and creating the blast wave, can result in breaking and dispersion of coarse inclusions. Thus preliminary irradiation of the alloy D16 plates makes it possible to reduce dispersoids and decrease the size of coarse inclusions.

Mechanical tests were conducted in the temperature range T=713-183K. The largest elongation at rupture was demonstrated by samples (irradiated and unirradiated) which were deformed at T=773K. The elongation at rupture δ as a function of the applied yield stress σ for unirradiated samples is demonstrated in Fig. 3 (line 1). One can see that samples showed a rather low values of elongation at rupture. Dependence of $\delta$ on $\sigma$ has a maximum, when $\sigma$=3.0 MPa ($\delta$=72%). Dependence of $\delta$ on $\sigma$ for irradiated samples is shown in Fig. 3 (line 2). One can see that for the low strains the value $\delta$ is larger for irradiated samples. The maximum of $\delta$, as for unirradiated samples, is realized when $\sigma$=3.0 MPa ($\delta$=133%).

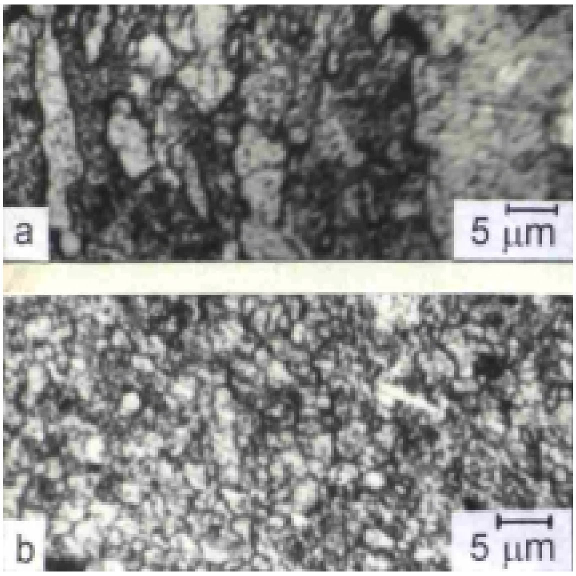


*Fig. 1. Microstructure of D16 alloy: a) initial; b) after irradiation.*

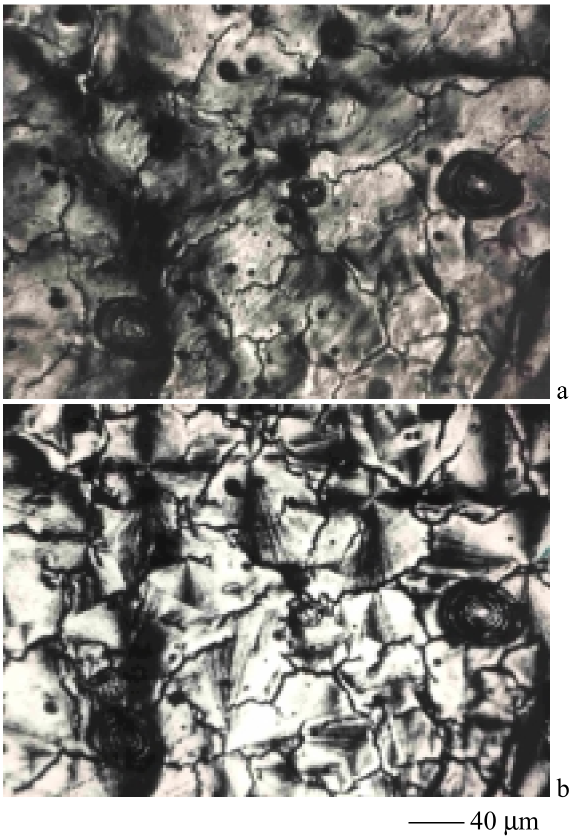


*Fig. 2. View of the surface of irradiated alloy D16 plate: a) in ordinary light; b) in polarized light.*

Although unirradiated samples have the elongation at rupture almost in 2 times less then irradiated ones, nevertheless one and another have phenomenological parameters peculiar to superplastic materials. Therefore, probably, grain boundaries are in a nonequilibreium state, typical for superplasticity, that makes possible their intensive creeping. However, the cause of a quick breaking of deformed samples probably is the existence of coarse inclusions of undissolving phases. Irradiation, apparently, makes it possible to decrease a size of inclusions and increase $\delta$.

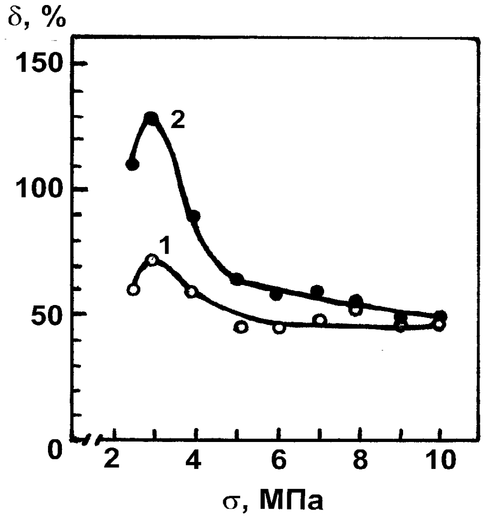


*Fig. 3. $\delta$ versus $\sigma$ for D16 alloy. 1 - without irradiation; 2 - with irradiation.*

## 4 CONCLUSION

1. Irradiation of the alloy D16 plates with a pulsed relativistic electron beam leads to formation in them the ultrafine-grained and uniaxial structure.
2. Parameters of superplastic flow of irradiated samples are better then these of unirradiated ones. This is probably related with distinction in grains and redistribution of consolidating phase particles.

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