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CHANGE IN PHASE LATTICE SPACING IN Al – Si ALLOYS AFTER ELECTRON-BEAM TREATMENT

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Surface layers of alloys Al – 5% Si, Al – 10% Si and Al – 20% Si after electron beam treatment with different energy densities (10, 30 and 50 J/m^2) are studied. X-ray diffraction phase analysis is used to determine the phase composition of a surface layer and phase lattice constant after irradiation and in the initial condition. It is shown that irradiation of Al – Si alloys with an electron beam is accompanied by changes in phase lattice constants within a surface layer, which may be connected with changes in alloying element concentration.

Keywords: crystal lattice spacing, electron beam, aluminum alloy, Al – 5% Si, Al – 10% Si, Al – 20% Si.

INTRODUCTION

Treatment by concentrated streams of energy is one of the most important methods for improving material surface properties, and their elemental and phase compositions. In this case the structure and properties of the main volume of an object remain unchanged [1]. Among the most studied and extensively used methods for treating a material surface with concentrated flows of energy it is possible to separate ionic [2, 3], and laser [4, 5] radiation, and also radiation by pulsed electron beams [6, 7]. Among these methods a relatively new procedure is treatment of a material surface with a strong beam of electrons [8, 9]. This beam of electrons, exhibiting high energy ($1 \times 10^8 - 1 \times 10^9$ W/cm^2) acts on a thin surface layer (less than tens of microns) for a short time (microseconds) that makes it possible to conduct extremely rapid surface heating and cooling. Within work of various scientific organization it has been demonstrated that treatment of a material surface with a strong electron beam causes formation of metastable microstructures such as a supersaturated slid solution [10] and ultrafine grain size [11], and nanostructures [11, 12] which affects to a significant effect finished object physical and mechanical properties.

In our previous published work [13, 14] the structure and mechanical properties have been studied for silumins after treatment with concentrated energy beams.

The aim of the present work is a study of the phase composition and crystal lattice spacing in alloys of the Al – Si system with a different silicon content subjected to treatment by a high intensity pulsed electron beam with a different energy density.

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TABLE 1. Chemical Composition of Alloys Al – 5% Si, Al – 10% Si, and Al – 20% Si

Alloy	Element content, wt.%									
	Al	Si	Fe	Cu	Mg	Mn	Ni	Ti	Cr	Zr
Al – 5% Si	90.50	5.39	0.64	1.330	0.65	0.240	0.170	–	–	1.08
Al – 10% Si	84.88	11.10	0.25	2.190	0.58	0.020	0.920	0.050	0.010	–
Al – 20% Si	78.52	20.28	1.14	0.072	–	0.015	0.006	0.006	0.001	–

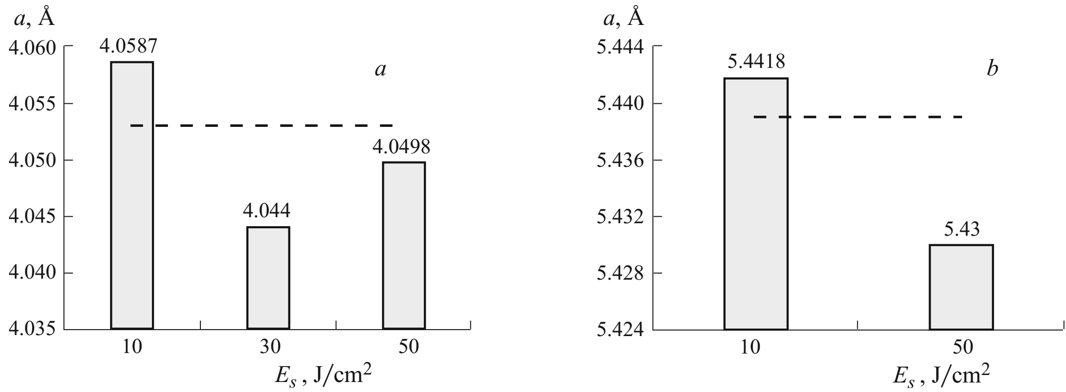

Fig. 1. Dependence of α_{Al}-phase (*a*) and Si-phase (*b*) crystal lattice spacing within surface layer of alloy Al – 5% Si on electron beam energy density during EBT (broken lines show value of phase lattice spacing within alloy in original condition).

METHODS OF STUDY

Hypoeutectic alloys Al – 5% Si, Al – 10% Si, and hypereutectic alloy Al – 20% Si were studied. Alloy chemical composition (x-ray spectral analysis results) are provided in Table 1.

Rectangular specimens with a size of 15 × 15 × 5 cm were prepared for study. The surface of a specimen was ground and polished to a mirror finish. Then electron-beam treatment (EBT) was performed in a SOLO laboratory unit [15]. The phase composition of a specimen surface layer was determined after EBT with a different highly condensed pulsed electron beam intensity: E_s = 10, 30, and 50 J/m^2) (alloys Al – 5% Si and Al – 10% Si) and E_s = 25 and 35 J/m^2) (alloy Al – 20% Si). The rest of the electron beam parameters were constant for all specimens: electron acceleration energy 17 keV, pulse time 200 μsec, amount of pulses 3; pulse sequence frequency 0.3 sec^{-1}, residual gas pressure (argon) within the unit working chamber 2×10^{-2} Pa. The phase composition was studied by x-ray phase analysis in a Shimadzu XRD 6000 diffractometer.

RESULTS AND DISCUSSION

Alloy Al – 5% Si. It has been established that the main phases in the original composition of alloy Al – 5% Si are a solid solution based on aluminum (α_{Al}-phase), silicon (Si-phase), and also presence of silicon nitride (Si_3N_4 phase).

Irradiation of alloys Al – 5% Si by a pulsed electron beam of different intensity is accompanied by a change in α-phase crystal lattice spacing. Analysis of results presented in Fig. 1*a* show that with E_s = 10 J/cm^2 the α_{Al}-phase of alloy Al – 5% Si reaches a maximum value (*a* = 4.0587 Å), which is significantly higher than the original (*a* = 4.0531 Å). With E_s = 30 J/cm^2 the α_{Al}-phase lattice spacing decreases to a minimum value of *a* = 4.044 Å, and with E_s = 50 J/m^2 it increases again to *a* = 4.0498 Å.

The crystal lattice spacing of the Si-phase in Al – 5% Si after EBT was also studied. It has been established that after radiation with E_s = 10 J/cm^2 the Si-phase has *a* = 5.4418 Å, which is significantly above the original value (*a* = 5.4391 Å) (see Fig. 1*a*). With E_s = 50 J/m^2 the Si-phase lattice spacing is reduced to *a* = 5.430 Å.

Al – 10% Si. The main phases in Al – 10% Si in the original condition, as also in alloy Al – 5% Si, include α_{Al}-phase, silicon (Si-phase), and Si_3N_4.

After EBT alloy Al – 10% Si with a different beam density the α_{Al}-phase crystal lattice spacing changes. It may be seen in Fig. 2*a* that with an increase in beam density from 10 to 30 J/cm^2 the α_{Al}-phase crystal lattice spacing is reduced from *a* = 4.0481 Å to *a* = 4.0444 Å. With E_s = 50 J/cm^2 a minimum value is observed: *a* = 4.0435 Å, which is less than the original value *a* = 4.0502 Å.

After EBT with E_s = 10 and 30 J/cm^2 alloy Al – 10% Si-phase lattice spacing *a* = 5.4277 and 5.4180 Å respectively, which is lower than the original value (*a* = 5.4309 Å). With E_s = 50 J/cm^2 the spacing is reduced to a minimum (*a* = 5.4039 Å), which is also less than the original (Fig. 2*b*).

Alloy Al – 20% Si. The main phases of alloy Al – 20% Si in the original condition are α_{Al}-phase, Si-phase, silicon nitride Si_3N_4, and AlSi intermetallic. A study of the phase composition of the alloy surface after EBT with a different density showed (Fig. 3) that with a value of E_s from 25 to 35 J/cm^2 the lattice spacing decreases insignificantly, i.e., from *a* = 5.4341 to 5.4437 Å, but it remains above the original value (*a* = 4.046 Å. In contrast to this the AlSi phase lattice spacing is unchanged after EBT with E_s = 25 and 35 J/cm^2.

It may be suggested that the reason for the change in phase crystal lattice spacing in alloys Al – 5% Si, and Al – 10% Si after EBT is a change in alloying element concentration within them. From analysis of data in [16] it follows that for magnesium it is greater than for aluminum. The dependence of crystal lattice spacing for aluminum on pulse dura-

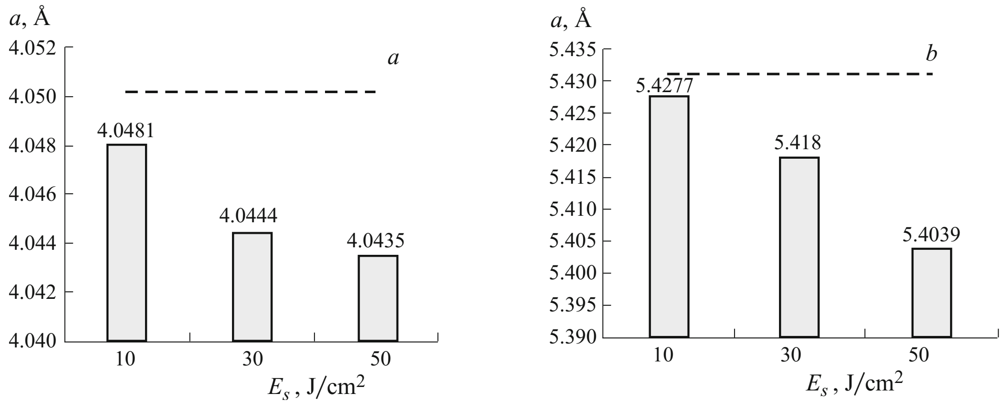

Fig. 2. Dependence of α_{Al}-phase (*a*) and Si-phase (*b*) crystal lattice spacing within surface layer of alloy Al – 10% Si on electron beam energy density during EBT (broken lines show value of phase lattice spacing within alloy in original condition).

tion and electron beam energy density will be determined by a process of dissolution and repeated precipitation of silicon particles and intermetallics proceeding during material irradiation by a pulsed electron beam.

CONCLUSIONS

The phase composition of alloy Al – 5% Si, Al – 10% Si, Al – 20% Si surface layers modified with an electron beam is analyzed, and the dependence of phase crystal lattice spacing on electron beam energy intensity are analyzed. It is shown that with irradiation of alloys Al – 5% Si and Al – 10% Si by a pulsed electron beam is accompanied by a change in crystal lattice spacing of the main phases, i.e., solid solution based on aluminum (α_{Al}-phase) and silicon (Si-phase). The maximum lattice spacing for these phases is achieved with a beam energy density of $E_s = 10$ J/cm^2 (alloy Al – 5% Si,) and 50 J/cm^2 the (alloy Al – 10% Si) causes a reduction in lattice spacing to a minimum.

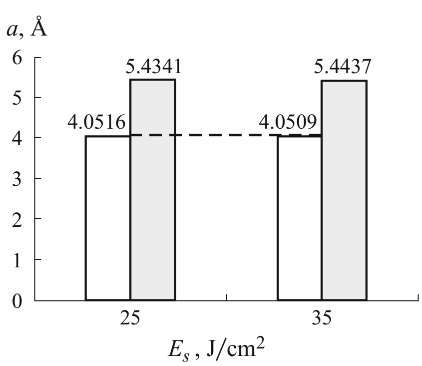

Fig. 3. Dependence of AlSi-phase (colored columns) and Si-phase (shaded columns) crystal lattice spacing within alloy Al – 20% Si surface layer on electron beam energy density during EBT (dotted line shows value of phase lattice spacing within alloy in the original condition).

Irradiation of alloy Al – 20% Si by a pulsed electron beam is accompanied by a change in AlSi and Si phases crystal lattice spacing. The crystal lattice spacing for Si-phase with an electron beam energy density of 25 and 35 J/cm^2 is 5.4341 and 5.4437 Å respectively, which is higher than its original value (4.046 Å). The crystal lattice spacing for AlSi phase is unchanged with irradiation with a beam s density of both 25 J/cm^2 and 35 J/cm^2.

It may be proposed that the reason for a change in crystal lattice spacing in aluminum alloys is a change in alloying element concentration within phases.

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