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RBS analysis of rapidly solidified Al–Si–Ti alloy with Fe and Ni dopes

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Abstract

By means of Rutherford backscattering spectroscopy technique, a detailed element analysis of a rapidly solidified Al–9.6Si–0.8Ti (at%) alloy with Fe and Ni dopes has been investigated. It was found that the 0.02 μm thick surface layer of the ribbon is enriched with Si (24.0 at%) and Bi impurity (0.007 at%). Oscillations of non-uniformly Si depth distribution through the ribbon thickness were found at the ribbon surface layer (up to 0.2 μm in thickness). At the 140 °C annealing, Si atoms diffuse from the volume to the ribbon surface. Its concentration at the thin surface layer increases by 25%. At 500 °C, there is a redistribution of all alloy components. Dope elements diffuse into the ribbon volume, but Bi diffuses on the ribbon surface, reaching 0.06 at%. Si oscillations weaken, thickness of the layer in which they are detected extends to 0.4 μm.

Keywords: Rapid solidification; Aluminium alloys; Depth profiles; Rutherford backscattering spectroscopy

1. Introduction

Industrial importance of Al–Si system alloys results from their high capability of flowing in the liquid state, low propensity to shrinkage formation at casting, opportunity of soldering and welding [1,2]. Ti, Fe and Ni are widely used as modifying dopes in Al–Si alloys. Rapid solidification processing (RSP) is a well-established method for preparation of metals in metastable states, giving access to a range of novel materials properties [1,3]. As it is generally known, properties of alloys depend both on composite structure, and the content of accompanying impurities. In a number of binary systems that we have studied, such as Al–X (X = Fe, Co, Cu, Ge, Sb), we established that the solute elements are distributed irregular in a near-surface region (up to 1.2 μm) of the rapidly solidified (RS) alloys [4–8]. Previous study [9] of the composition of the RS Al–Si–Ti alloy has shown that the ribbon surface layer is depleted of Ti and enriched with Fe and Ni dopes. In this study, the distribution patterns of the Si dope element and Bi impurity which is accompanied by Si in the RS Al–Si–Ti alloy and the effect of

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annealing on the solute distribution have been examined by Rutherford backscattering spectroscopy (RBS). Due to high sensitivity of RBS to heavy elements and computerized data interpretation by the RUMP program [10], there was for the first time distribution of the small solute concentration (up to 0.001 at%) in the investigated RS Al alloy ribbons. We have determined Ti and Fe with Ni concentration using the computer simulation of Si and Al signals on the spectra in comparison with preliminary research [9]. It is assumed that the presence of Ni increases thermal stability of Al alloys and strength limit of RS Al–Si–Fe alloys [11]. Fe contents in Al–Si alloys should be limited to ~0.2 at% as it reduces their ductility.

2. Experimental details

The microcrystalline Al–9.6Si–0.8Ti (at%) alloy with 0.15Fe and 0.07Ni dopes were produced by RSP described elsewhere [4]. The melt-cooling rate was of the order of 10^6 K/s. The ribbons studied were approximately 10 mm wide and 30–50 μm in thick. The samples were isothermally annealed at 140 and 500 °C for 2 h. The solute profiles were measured by the RBS technique using 2.0 MeV He^+ ions (laboratory scattering angle of 168°). The RBS depth resolution was 0.04 μm. The relative error of concentration definition of Al and Si in the alloy made 1%, O—6%, the Ti, Fe and Ni did not exceed ~10%, and Bi impurity—30%.

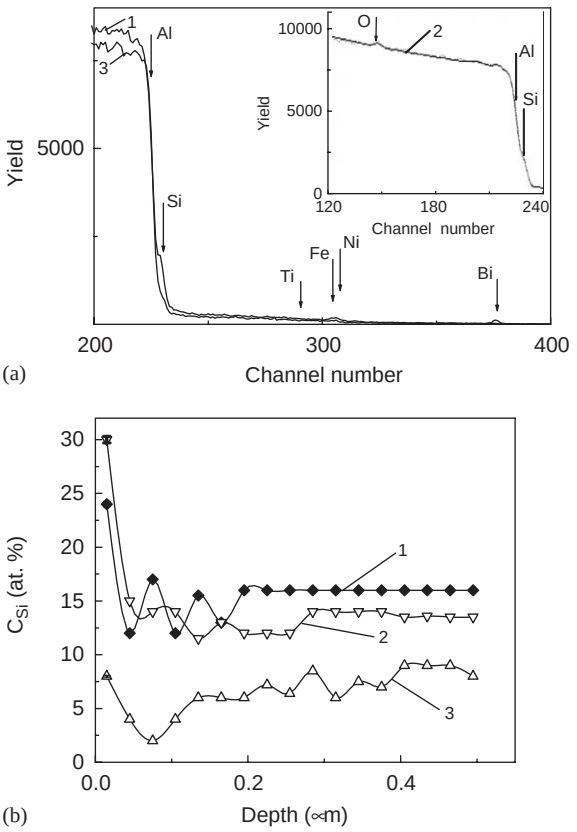

Fig. 1. Dope-depth distribution in rapidly solidified foils of Al–Si–Ti alloy: (a) RBS spectra of He^+ ions with $E = 2.0$ MeV from (1) as-cast, (2) annealed at 140 °C and (3) annealed at 500 °C foils, (b) Si concentration-depth profiles in the foils. The inset shows the experimental spectrum 2 with simulated spectrum by RUMP (solid line). The arrows indicate the positions of signals on a channel scale from the alloy elements.

3. Results and discussion

For RS ribbons of Al–Si–Ti alloy, irregular element distribution has been observed. The typical RBS spectra from the as-cast and annealed ribbons are shown in Fig. 1a, together with the spectrum fitted by RUMP (inset of Fig. 1a). In the alloy Bi, accompanying impurity of Si is found. It should be mentioned that the experimental RBS spectra and the simulated profiles fit very well. As Fe and Ni are adjacent in the periodic system, the signals from them on the spectra do not differ. That is why at the composite analysis, their total amount was determined. Energy signal position from Al and Si on the spectra does not differ practically (channel numbers $N_{Al} = 224.8$ and $N_{Si} = 230.1$). However, the amounts of Si and Al in the alloy are maximum, hence, the use of RUMP program allows to determine Si depth distribution. Fig. 1b summarizes the results obtained by the RUMP simulation for the Si concentration-depth profiles in the Al–Si–Ti alloy.

It is established that the ribbon thin surface layer (0.02 μm) of Al–Si–Ti alloy is enriched with