CHARACTERIZATION OF PRECIPITATES FORMED IN THE ALUMINUM ALLOY WITH ANTIMONY

Krzysztof Matuš[1*], Klaudiusz Gołombek[1], Peter Palček[2], Paulina Boryło[1]

[1]Institute of Engineering Materials and Biomaterials, Silesian University of Technology, Konarskiego 18A, 44-100 Gliwice, Poland, e-mail: krzysztof.matus@polsl.pl
[2]Department of Materials Science, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1, Žilina 010 26, Slovak Republic e-mail: Peter.Palcek@fstroj.uniza.sk

Abstract:
The aim of the article was to identify and characterize the precipitates formed in the aluminum alloys with the addition of antimony. The performed investigation was on the casting aluminium alloy based on ENAC-AlMg5Si2Mn (ENAC-51500) used in the automotive industry with the addition of antimony in an amount of 0.2 % for the first sample and 1.2 % for the second one. The main research technique was scanning electron microscopy, in order to evaluate the morphology and precipitates in the investigated samples, the backscattered electrons were used. Performed research allowed to determine the effect of the addition of antimony on the morphology of formed precipitates.

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1. INTRODUCTION

Aluminium alloys are one of the most common groups of construction materials; their widespread use is due to the low density, high strength and good toughness at reduced temperatures. The main alloying elements in aluminum alloys are silicon, magnesium, manganese, copper and zinc. Complex chemical composition of these alloys results in complex precipitations occurring in them. For this reason, numerous attempts have been taken to obtain the information on precipitates present in aluminum alloys.

So far carried out research focused on the study of the most common precipitates such as phase β' and β'' in alloys Al-Mg-Si and Al-Mg-Si-Cu. The most commonly used technique of analysis that allows defining both the crystalline structure of precipitates, as well as their chemical compositions, is the transmission electron microscopy [1-5].

Other phases, described in the literature, occurring in aluminium alloys are the precipitates of the θ, S, η' phases. The main research techniques used to identify to the precipitates are transmission electron microscopy and x-ray crystallography. These techniques examine the structure and chemical composition of these precipitates and the approximation mechanism of their release. However, these precipitates are still in the area of interest of currently performed studies [6-9].

The study of mechanical properties of aluminium alloys was extensive, focusing mainly on endurance and strengthening the processes of precipitation in these alloys [10-13]. In the case of laser alloying and surface modification of aluminum alloys, main areas of interest are the study of abrasion resistance of molten layers and the effect of additives on the mechanical properties, as well as testing the corrosion resistance of obtained melted layers [14-20].

The influence of the age-hardening of aluminum alloys produced in precipitates of these alloys has been previously described in detail. Performed research has focused on mechanical properties obtained during the heat treatment [1,2,7], or in the case of laser alloying of its impact on the functional properties of aluminum alloys [18,20-22].

*CONTACT: Krzysztof Matuš, Krzysztof.Matus@polsl.pl

The separation occurring in aluminium alloys have a nanometric size [3,5,9,10,22]. The process of precipitation hardening of the matrix results in dissolution of precipitates, and the re-release of the ageing time. Thus, the result of separation can be different chemical composition and unit cell sizes of the precipitates formed in the low-alloyed aluminum alloys.

Due to the presence of high-melting phase in aluminum alloys having a very high melting point, at the time of solidification, they nucleate at first. The interfacial boundary is a preferred place for nucleation of other precipitates. The use of antimony, as an element modifying the shape of eutectic aluminum silicon, and as a component of high-melting phase, is confirmed by several scientific papers published to date [22-30].

2. MATERIALS AND METHODS

The main research technique, which was used to characterize the tested materials, was the scanning electron microscopy (SEM). Observation of the structure morphology of aluminum alloy was made in a high-resolution scanning electron microscope Zeiss Supra 35, at an accelerating voltage of 20 kV. The main advantage of the use of scanning electron microscopy is the possibility for imaging and performing both qualitative and quantitative chemical analysis using the energy dispersive spectroscopy (EDS) with nanometric resolution. To evaluate the morphology and precipitates in the investigated samples, the backscattered electrons (BSE) were used.

The casting aluminum alloy based on ENAC-AlMg5Si2Mn (ENAC-51500) used in the automotive industry (due to the high ductility and strength) was doped by antimony in an amount of 0.2 % for sample 1 and 1.2 % for sample 2. Chromium in an amount of 0.4 % was added to the melted alloy. Preliminary analysis shows that the concentration of antimony obtained for a sample 1 was 0.07 % and for sample 2 it was 0.14 %, which is well below the expected levels. After removal of the manganese antimony reached 0.16 for sample 3 and 1.05 for sample 4 (Tab. 1).

Table 1. Chemical composition of samples

Elements	Si	Mg	Cr	Mn	Sb	Al
Sample 1	2.20	5.5	0.4	0.87	0.07	rest
Sample 2	2.20	5.5	0.4	1.05	0.14	rest
Sample 3	2.20	5.5	0.4	-	0.16	rest
Sample 4	2.20	5.5	0.4	-	1.05	rest

3. RESULTS AND DISCUSSION

For the samples labelled as 1 and 2 the antimony was added during the casting process. Precipitates of antimony have a globular shape and are located between the grains of aluminium and eutectic (Figs. 1 and 2). For samples marked as 3 and 4, in which the Mn content was zero, the precipitates of antimony have changed their morphology from the globular to irregular. There are also the most often together with the precipitates of the Al-Mg-Cr (Fig. 3 and 4, Table 2). After melting and rapid cooling of the samples 3 and 4 precipitates of antimony (Table 3) decreased their diameter and had a globular shape (Figs. 5-8).

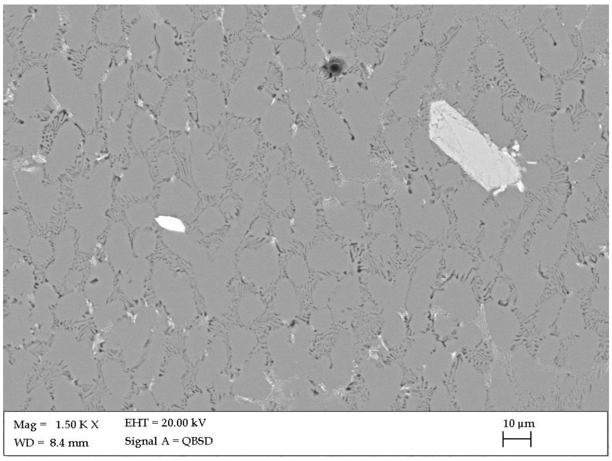

Fig. 1. The SEM image of the surface topography for sample 1 – 0.2 % Sb

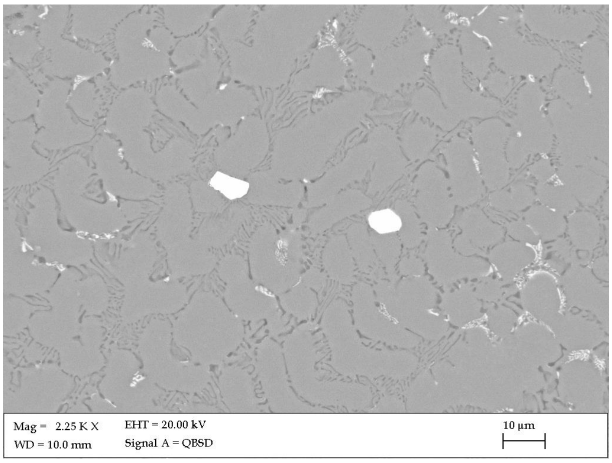

Fig. 2. The SEM image of the surface topography for sample 2 – 1.2 % Sb

Table 2. Chemical composition of Al-Mg-Cr precipitates presented in Fig. 3

ELEMENT	WT%	AT%
Alk	77.81	87.36
Crk	13.11	07.63
Mnk	09.08	05.01
Matrix	Correction	Zaf

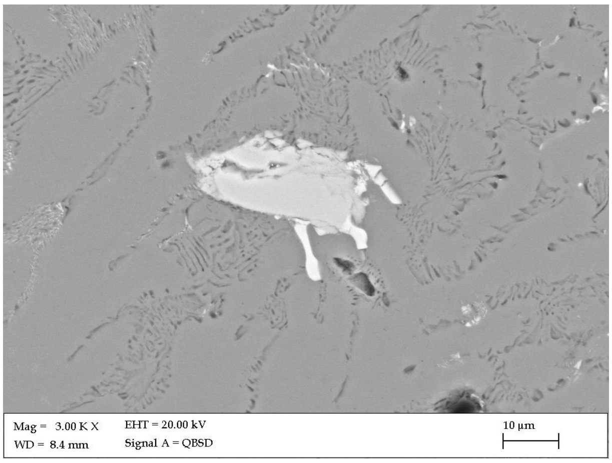

Fig. 3. The SEM image of the surface topography for sample 3 – 0.2 % Sb without Mn

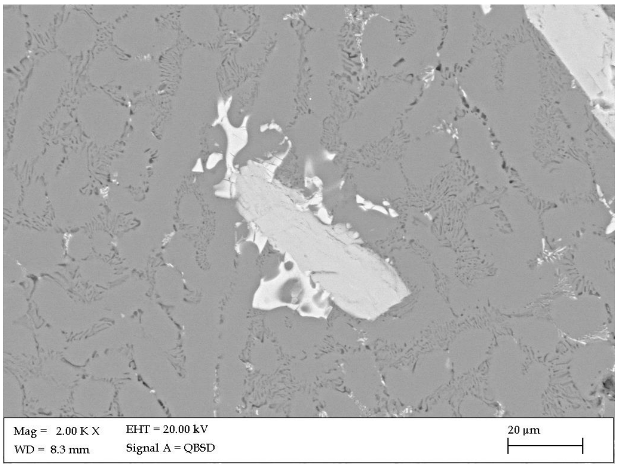

Fig. 4. The SEM image of the surface topography for sample 4 – 1.2 % Sb without Mn

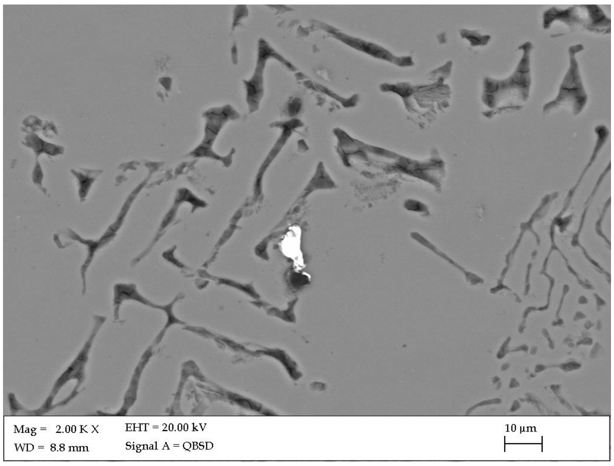

Fig. 5. The SEM image of the surface topography for sample 3 after melting and rapid cooling

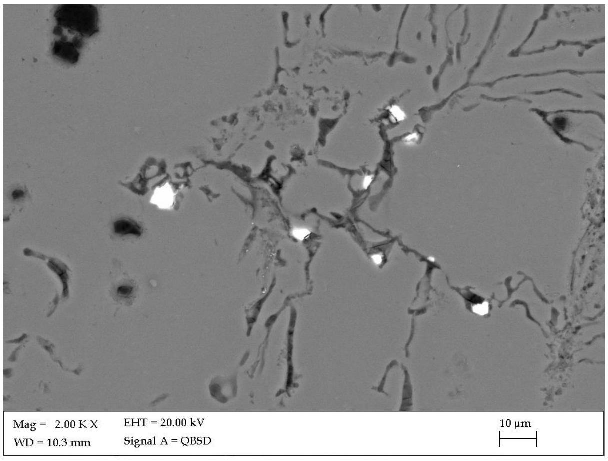

Fig. 6. The SEM image of the surface topography for sample 4 after melting and rapid cooling

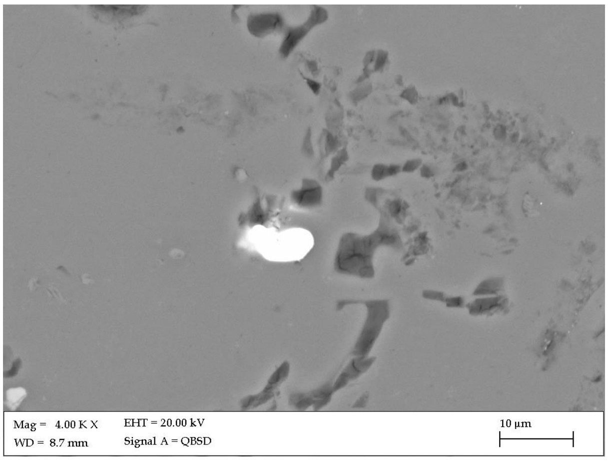

Fig. 7. The SEM image of precipitates for sample 3 after melting and rapid cooling

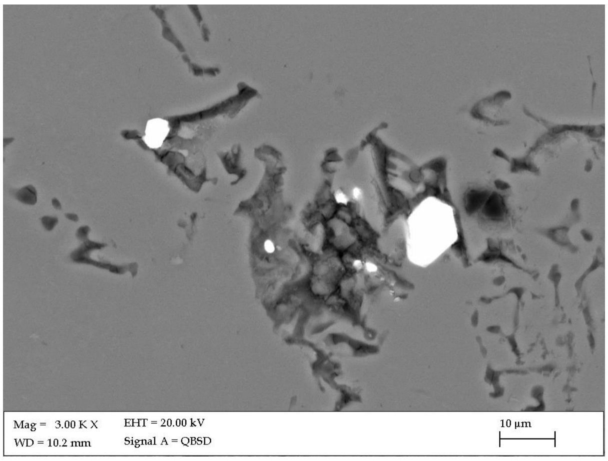

Fig. 8. The SEM image of precipitates for sample 4 after melting and rapid cooling

Table 3. Chemical composition of antimony precipitates

ELEMENT	WT%	AT%
Mgk	22.60	58.23
Alk	01.08	02.50
SbI	76.32	39.27
Matrix	Correction	Zaf

4. CONCLUSION

Casting of aluminum alloy with the designation ENAC-AlMg5Si2Mn (ENAC-51500) after addition of antimony in the range of 0.2 to 1.2 results in the formation of globular antimony precipitates in the structure of the alloy.

The addition of manganese alloy causes a decrease in the maximum saturation of the alloy with antimony to 0.2 atomic %. Lack of manganese in the alloy results in a much higher saturation of alloy with antimony, making it possible to achieve the target of 1.2%. Lack of manganese in the alloy changes the morphology of the precipitates from the globular to irregular.

Melting of the alloy and cooling it quickly changes the morphology of precipitates back to globular, while reducing the diameter of the precipitates.

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