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Synthesis of Base Alloys from the Al-Cu-Mg System, as a Precursor for Subsequent Amorphization

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Abstract
Method for synthesis of alloys from the Al-Cu-Mg system was developed. Three eutectic alloys with different compositions were synthesized. Two mass. % Zn was added to each of the Al-Cu-Mg alloys. The microstructure of the starting Al-Cu-Mg and of the obtained Al-Cu-Mg-Zn alloys was examined by light (LM) and scanning electron microscopy (SEM). The phase compositions of the alloys were characterized by X-ray diffraction (XRD) analysis.

Keywords: aluminum alloys, alloys Al-Cu-Mg, Al-Cu-Mg-Zn

1. Introduction

The synthesis of amorphous aluminum-based alloys is traditionally based on multicomponent systems containing aluminum (80–92 at. %), rare earth metals (3–20 at.%), transition metals (1–15 at.%) etc. [1-3]. All these compositions are expensive and this limits their application. The main challenge for scientists today is to obtain new aluminum alloys without rare earth elements, which have a high glass-forming ability (GFA).

The Al-Cu-Mg system is selected as the starting system for the synthesis of relatively new, not well-studied alloys, because aluminum alloys are widely used in the aviation and automotive industries. Moore over, this system contains frequently used and affordable metals It is expected that during amorphization the alloys of the Al-Cu-Mg system will have high (GFA) and their study will contribute to the in-depth study of the structural relaxation and kinetics of the glass transition It is also of interest the influence of other elements, such as Zn, added to the base alloys on their glass-forming ability.

The aim of the present study is to obtain Al-Cu-Mg alloys with compositions close to the compositions of the triple eutectic and Al-Cu-Mg-Zn alloys (2%Zn), intended for the subsequent production of amorphous ribbons and study of their mechanical properties and corrosion behavior.

2. Experiments

Three types of alloys were synthesized (Table 1), whose compositions 2a, 3a, 4a correspond to the compositions of triple eutectics from the Al-Cu-Mg diagram [4]. The alloy compositions are selected on the basis of the known facts that eutectic alloys are more easily amorphized and that the aluminum-copper ligature can contain from 33% (eutectic composition in the Al-Cu system) to 50% copper. The most commonly prepared ligatures contain up to 35% Cu. These

ligatures have a low melting point (575 ° C) and are chemically homogeneous. The preparation of Al-Cu ligature is relatively easy and good quality of the casting is achieved.
Purity metals Al-99.99%; Cu- 99.99% and Mg- 99.8%were used to prepare the alloys.

Table 1. Composition of AlCuMgZn alloys

	Al [%mass]	Cu [%mass]	Mg [%mass]	Zn [%mass]
Alloy 2a (2b)	61	33	6	2 (by synthesis)
Alloy 3a (3b)	61,61	30,43	7,96	2 (by synthesis)
Alloy 4a (4b)	56,8	34,4	8,8	2 (by synthesis)

The synthesis of Al-Cu-Mg alloys was carried out in an installation established at IMSETHAC-BAS. It consists of a resistance electric furnace, powered and controlled by a programmable thermostat RT 1800, manufactured by COMECO – Bulgaria. The resistance electric furnace is installed in a water-cooled, pneumo-vacuum chamber (Fig. 1) in an argon environment, with a purity of 99.998%.

Figure 1. Photograph of the pneumatic-vacuum chamber

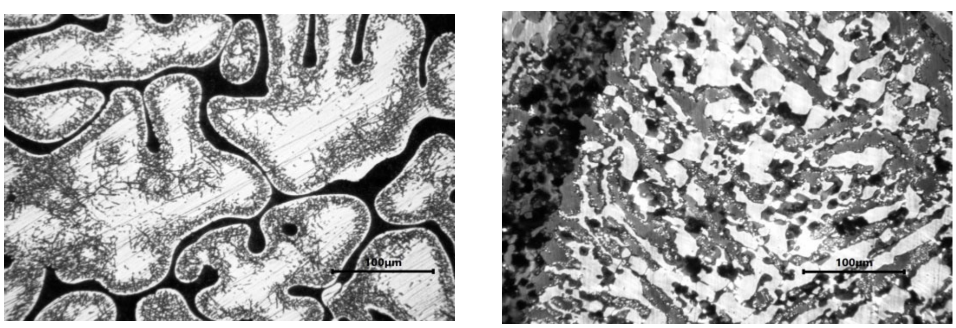
The synthesis results in an ingot with a diameter of about 20 mm and a height of about 30 mm. Four ingots were obtained from each composition of the alloys. To the composition of two of the obtained ingots is added about 2 wt. % high purity zinc (for analysis) as described below.
The resulting Al-Mg-Cu joint was placed in a cold double corundum crucible. under a backfill of equimolar flux layer, which is a mixture of chloride salts 50% NaCl – sylvinite and 50% KCl – sylvan.
The corundum crucible is heated in a crucible cantaloupe electric furnace at a speed of 12 degrees / min. It was found that at a temperature of 500ºC, measured near the surface of the melt, the ligature is still solid below the flux. Melting of the ligature begins at a temperature of about 550ºC. At this temperature, the required amount of zinc granules (for compositions containing Zn) is added under the flux and the melt under the flux is stirred with a quartz stirrer. At a temperature of 670ºC, measured near the melt surface, the flux begins to melt and the melt is stirred again. One hour after the start of the synthesis, at a temperature of about 700 – 720ºC,

the melt is stirred for the last time, the crucible is removed and placed on a refractory brick to cool to room temperature and the alloy to crystallize.
The alloys obtained after the addition of zinc are designated 2b, 3b and 4b respectively.
The photographs (Fig. 2) show alloys 4a and 4b – before and after the addition of zinc.

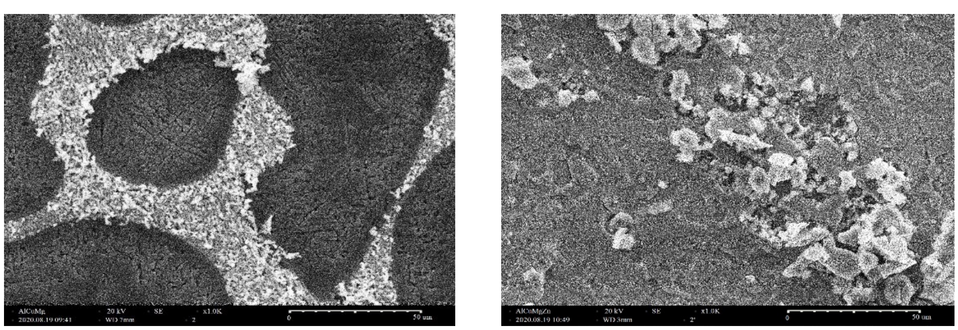
a. Alloy 4a Al-Cu-Mg   b. Alloy 4b Al-Cu-Mg Zn

Figure 2. Alloys Al-Cu-Mg (Zn) 4a and 4b

Samples with a thickness of about 1 mm were cut from the obtained ingots and metallographic sections for preparation of the microstructure were prepared by standard grinding and polishing. The study was performed by light microscopy (LM) of a ZEISS JENAVERT metallographic microscope and by scanning electron microscopy (SEM) of a scanning electron microscope HIROX 5500. The microstructure of alloys 2a, 3a, 4a before and of alloys 2b, 3b, 4b after the addition of 2 mass. % zinc was studied. The results are presented in figures 3, 4, 5.

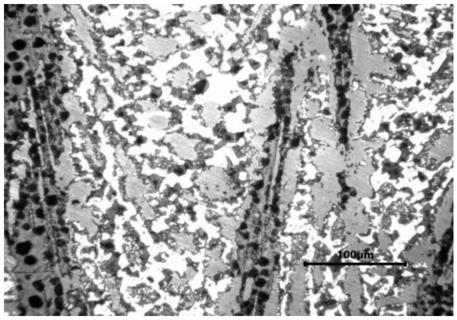


a. Alloy 2a, LM   b. Alloy 2b, LM

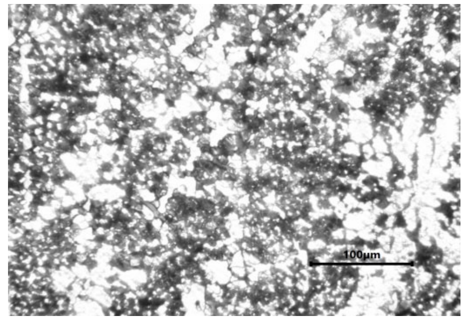


c. Alloy 2a, SEM   d. Alloy 2b, SEM

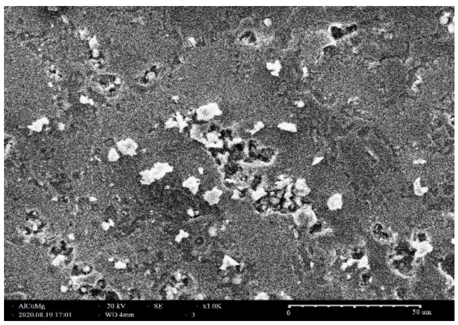
Figure 3. Microstructure of 2a Al-Cu-Mg and 2b Al-Cu-Mg-Zn alloys



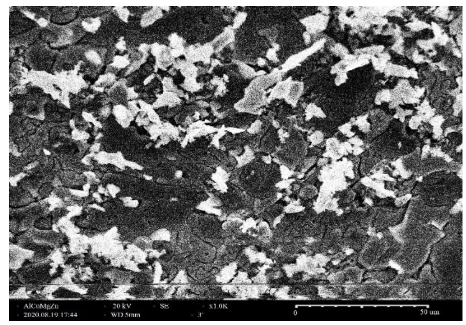
a. Alloy 3a, LM



b. Alloy 3b, LM

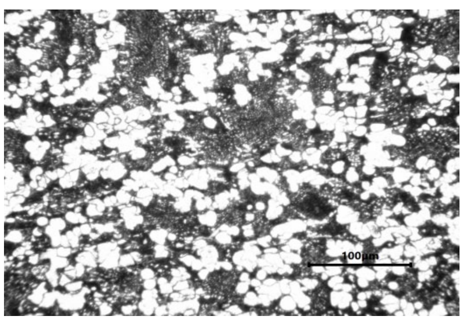


c. Alloy 3a, SEM

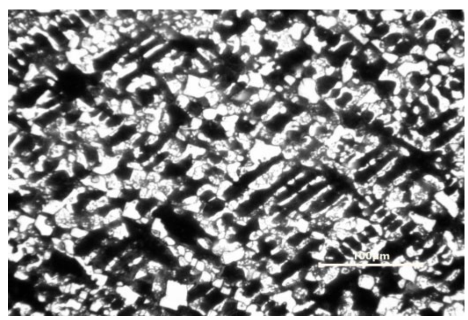


d. Alloy 3b, SEM

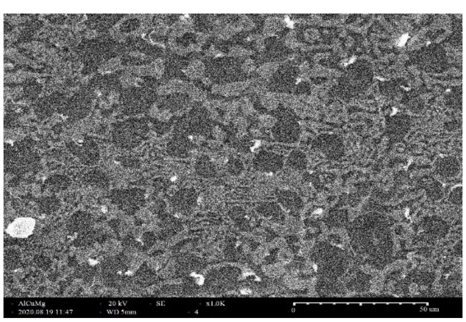
Figure 4. Microstructure of 3a Al-Cu-Mg and 3b Al-Cu-Mg-Zn alloys



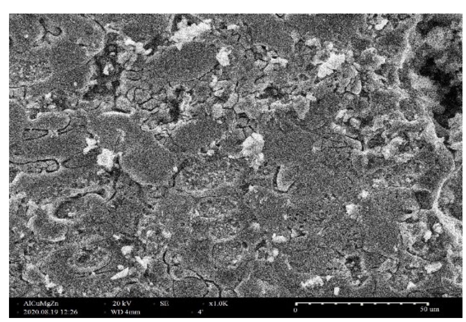
a. Alloy 4a, LM



b. Alloy 4b, LM



c. Alloy 4a, SEM



d. Alloy 4b, SEM

Figure 5. Microstructure of 4a Al-Cu-Mg and 4b Al-Cu-Mg-Zn alloys

The microstructural analysis showed a clear inhomogeneity of the alloys. The most coarse is the structure of alloy 2, and the finest is the structure of alloy 4, under relatively identical production conditions.
The phase composition of zinc-containing alloys was characterized by X-ray diffraction analysis. XRD analysis was performed with a Bruker D8 Advance powder X-ray diffractometer with CuKα radiation (Ni filter) and LynxEye recording in a solid-state position-sensitive detector. The qualitative phase analysis was performed using the PDF-2 (2009) database of the International Data Diffraction Center (ICDD) using the DiffracPlusEVA software package.
It was found that in 2b, 3b and 4b alloys aluminum is in the range of 43÷47% with dimensions 44÷46 nm. It were separated Al2Cu 32%, 14% and 1% with size 41÷46 nm and Al2CuMg – 24%, 38% and 56% with size 44 ÷ 65 nm, respectively.

Conclusions

- Basic alloys $Al_{61}Cu_{33}Mg_{6}$; $Al_{61,61}Cu_{30,43}Mg_{7,96}$ and $Al_{56,8}Cu_{34,4}Mg_{8,8}$ are obtained.
- Alloys $Al_{61}Cu_{33}Mg_{6}$-Zn, $Al_{61,61}Cu_{30,43}Mg_{7,96}$-Zn and $Al_{56,8}Cu_{34,4}Mg_{8,8}$-Zn with. 2 wt.% Zn are synthesized.
- Microstructural and phase analysis of the synthesized alloys are performed.

Acknowledgements
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