Bulgarian Society for NDT
International Journal "NDT Days"
Volume VI, Issue 3, Year 2023

ISSN: 2603-4018
eISSN: 2603-4646

Al-Cu-Mg-Si Nanocrystalline Alloys Produced by the PFC Method

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Abstract
The rapidly solidified $(Al_{74}Cu_{16}Mg_{10})_{100-x}Si_x$ alloys were obtained by melting in an induction furnace and then rapidly quenched by the planar flow casting (PFC) method in installations, created at the IMSETHAC-BAS. By X-ray analyse were obtained data, that the microstructure of the alloys is nanocrystalline with sized particles with dimensions 16÷.90 nm. The crystallization temperature (Tx) and the solidus (Ts) and liquidus (Tl) temperatures of the produced alloys were determined.

Kaywords: Nanosized alloys Al-Cu-Mg-Si

1. Introduction

The production of aluminum-based amorphous 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 formulations are expensive and this limits their application. A major challenge for scientists today is to obtain new aluminum alloys without rare earth elements that have high glass-forming ability (GFA).

The Al-Cu-Mg system was chosen as the starting system for obtaining relatively new, not so well studied alloys, because aluminum alloys are widely used in the aviation and automotive industries. In addition, this system contains used and affordable metals. It is expected that upon amorphization, alloys of the Al-Cu-Mg system will be of high GFA and their study will contribute to the in-depth study of structural relaxation and glass transition kinetics. Also of interest is the influence of other elements, for example Zn, added to the base alloys on their GFA.

The aim of the present work is the preparation of Al-Cu-Mg-Si alloys with compositions close to the compositions of the ternary eutectic, intended for the subsequent production of amorphous ribbons and the study of their mechanical properties and corrosion behavior.

2. Experimental

Three types of alloys of the system Al-Cu-Mg-Si were synthesized. The compositions of the alloys were chosen on the basis of the known facts that eutectic alloys are more easily amorphized and that the aluminum-copper ligature can contain from 33% (the eutectic composition in the system Al-Cu) up to 50% copper. The most commonly prepared ligatures contain up to 35% Cu. These ligatures have a low melting point (575°C) and are uniform in chemical composition. Metals with purity Al-99.99% were used to produce the alloys; Cu-99.99%, Mg- 99.8% and Si- semiconductor purity (single crystal).

Table 1.

Designation of ribbons	Al, [%]		Cu, [%]		Mg, [%]		Si, [%]	
	Mass.	At.	Mass.	At.	Mass.	At.	Mass.	At.
$(Al_{74}Cu_{16}Mg_{10})_{96}Si_4$	60.33	72.33	29.79	15.17	6.34	8.44	3.54	4.07-
$(Al_{74}Cu_{16}Mg_{10})_{94}Si_6$	59.23	70.46	28.64	14.47	6.78	8.96	5.35	6.11
$(Al_{74}Cu_{16}Mg_{10})_{91}Si_9$	56.63	67.46	28.70	14.52	6.9	9.15	7.76	8.88

The synthesis of the Al-Cu-Mg alloys was carried out in an installation created at the IMSETHAC – BAS. It consists of a resistance electric furnace, powered and controlled by a programmable thermostat RT 1800, manufactured by the company "COMECO" – Bulgaria. The electric resistance furnace is installed in a water-cooled, pneumatic-vacuum chamber (Fig. 1) in an argon environment, with a purity of 99.998%. The synthesis is carried out at a temperature regime as follows: rise in temperature by 10ºC/min to 1050ºC and hold at this temperature for 120 min. and subsequent cooling with the furnace.

Fig. 1. Water-cooled, pneumatic-vacuum chamber

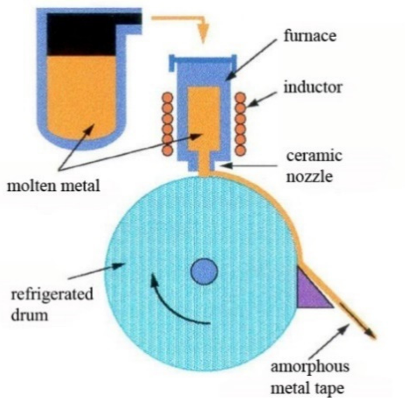
As a result of the synthesis, ingots with a diameter of about 20 mm and a height of about 30 mm are obtained.

Each of the resulting Al-Mg-Cu-Si ingots was placed in a cold double corundum crucible under a backfill of an equimolar layer of flux, which is a mixture of chloride salts 50% NaCl – sylvinite and 50% KCl – sylvine.

The corundum crucible is heated in a crucible canthal electric furnace at a rate of 12ºC/min. It was found that at a temperature of 500°C, measured near the surface of the melt, the ligature was still solid below the flux core. The melting of the ligature starts at a temperature of about 550°C. At a temperature of 670°C, measured near the surface of the melt, melting of the flux begins and the melt is stirred intensively. One hour after the start of the synthesis, at a temperature of about 700 – 720°C, the melt is stirred for the last time, the crucible is removed and placed on a refractory pad to cool to room temperature and the alloy to crystallize.

The flat casting (PFC) method was used to produce fast-solidified ribbons. The scheme for installing PFC equipment is shown in fig. 2, and figure 3 shows the laboratory installation for rapid melt solidification, built at IMSETHAC-BAS.

The resulting alloys are placed in a quartz nozzle with a tube diameter of 18 mm. The nozzle opening has a diameter of about 0.8 mm. The alloys are melted in an inductor to a temperature exceeding by 20-30ºC the melting temperature of the respective alloy. The molten alloy flows under an argon pressure of 0.4-0.5 atm on a copper disk with a diameter of 140 mm. The linear speed of the disc was in the range of 45-50 m/s. The resulting ribbons were about 2 mm wide and 27-30 µm thick.



Fig, 2 Scheme of PFC equipment.

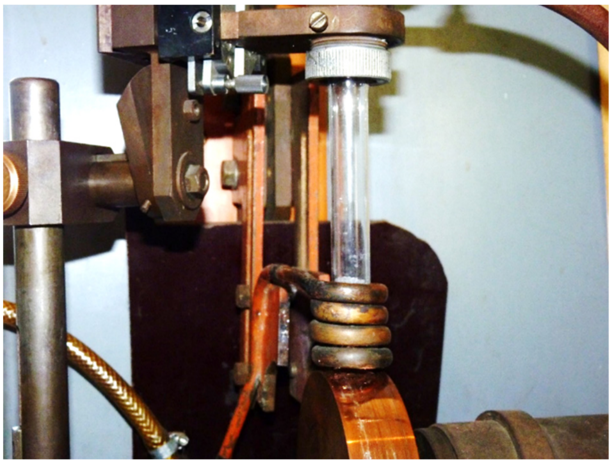
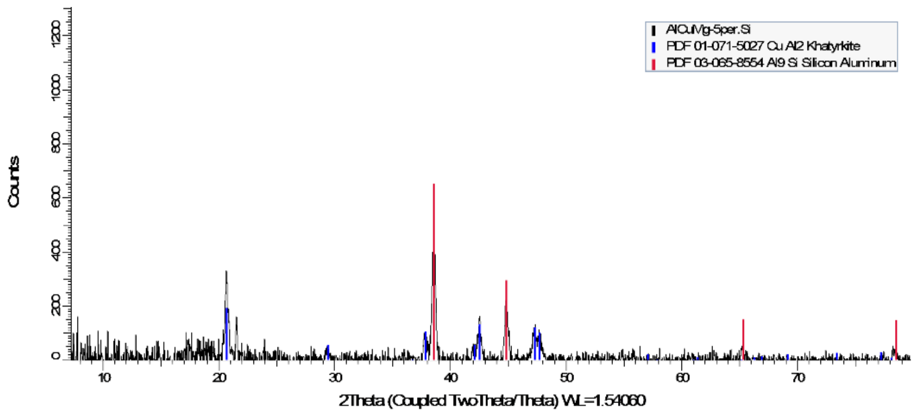


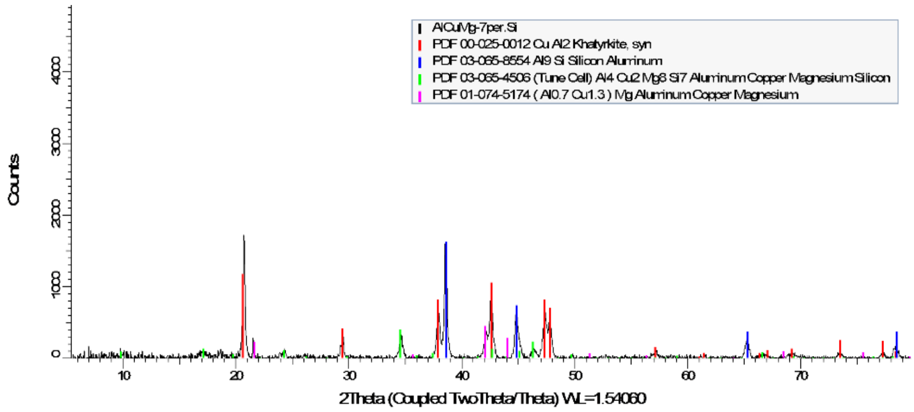
Fig. 3 Laboratory installation of PFC.

By means of X-ray diffraction analysis, the phase composition of the alloys containing silicon was characterized – (fig. 3) and the type and size of the separated phases were determined.



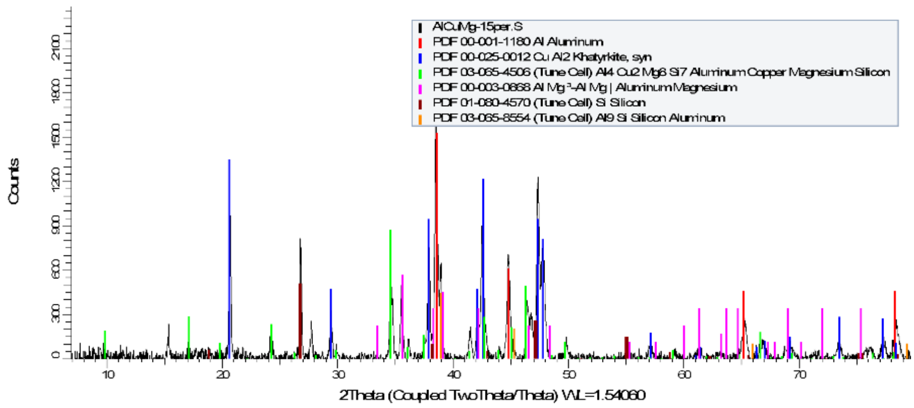
Dimensions: CuAl2-19nm (66%)   Al9Si-36nm (33%)

Fig. 3a. $Al_{74}Cu_{16}Mg_{10})_{96}Si_4$



Dimensions: CuAl2-42nm (52%); Al9Si-52nm (21%); Al4Cu2Mg6Si7-22nm(27%); Al0.7Cu1.3Mg-traces

Fig. 3b. $Al_{74}Cu_{16}Mg_{10})_{94}Si_6$

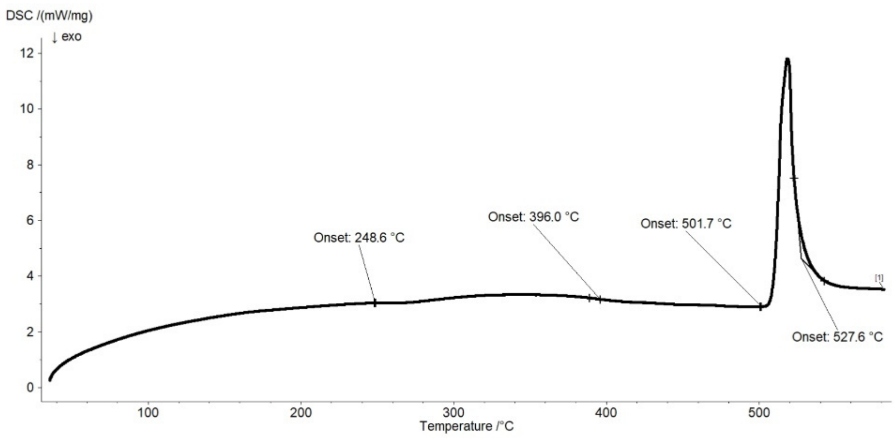


Dimensions: Al-53nm (5%), Al9Si-94nm (4%), CuAl2-62nm(24%), AlMg-55nm(41%), Si-90nm (9%)Al4Cu2Mg6Si7-40nm-fix(15%)

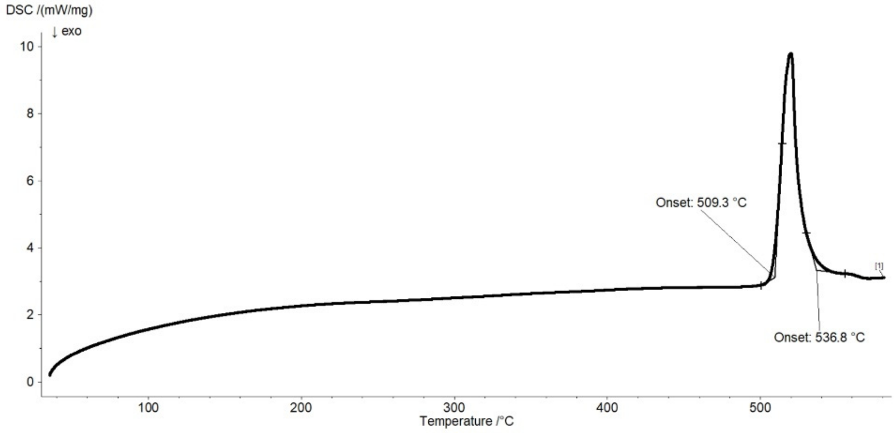
Fig. 3c. $Al_{74}Cu_{16}Mg_{10})_{91}Si_9$

The **DSC** analysis shown in Fig. 4 a, b, c of the obtained quick-hardened ribbons shows that only in alloy "c" there are beginnings of an amorphous phase.

a



b



c

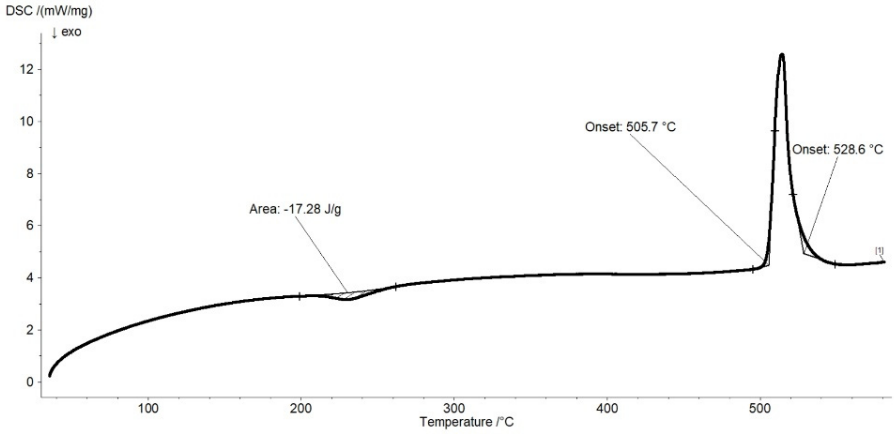


Fig. 4. DSC analysis of AlCuMg Si alloys

3. Conclusions

- Base alloys are obtained $(Al_{74}Cu_{16}Mg_{10})_{96}Si_4$, $(Al_{74}Cu_{16}Mg_{10})_{94}Si_6$ и $(Al_{74}Cu_{16}Mg_{10})_{91}Si_9$.
- By the PFC method from the alloys $(Al_{74}Cu_{16}Mg_{10})_{100-x}Si_x$ x=4, 6, 9 hardaned ribbons with a nanoscale microstructure were obtained.
- The phase composition was determined and the crystallization behavior of the obtained alloys was studied.

Acknowledgements

This study is funded by the project "Study of the rheological and corrosion behavior of amorphous and nanocrystalline aluminum-based alloys", Contract with BNSF №KP-06-H37/13 of 06 December 2019.

A part of experimental units used in this work was funded by the European Regional Development Fund within the OP "Science and Education for Smart Growth 2014 – 2020", project CoE "National center of mechatronics and clean technologies", No BG05M2OP001-1.001-0008-C08.

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