

HRTEM CHARACTERIZATION OF THE ALPHA-ALUMINUM PHASE OF MELT-SPUN QUATERNARY AL-SI-CU-MG ALLOYS. Ismeli Alfonso(1), Cuauhtémoc Maldonado(1), Gonzalo González(2), Ariosto Medina(1), Luis Bejar(3), Ignacio Mejía(1). (1)Instituto de Investigaciones Metalúrgicas, UMSNH, Edificio U, Ciudad Universitaria. CP 58000, Morelia, Michoacán. México; (2)Instituto de Investigaciones en Materiales, UNAM, Ciudad Universitaria. Apartado Postal 70-360, 04510. México, DF. México; (3) Facultad de Ingeniería Mecánica. UMSNH, Edificio W, Ciudad Universitaria. CP 58000, Morelia, Michoacán. México. Email: post18@jupiter.umich.mx.

The 319 aluminum alloy is one of the most widely used aluminum alloys in the automotive industry. This alloy presents silicon contents from 5.5 to 6.5 and copper in the range from 3.0 to 4.0 (in wt. %) [1]. Cast structure includes complex intermetallics [2]. Applying a rapid solidification process (RSP) it is possible to obtain a supersaturated solid solution with a higher quantity of alloying elements, and avoid or minimize the formation of second phases, mainly the insoluble $\text{Al}_5\text{Cu}_2\text{Mg}_8\text{Si}_6$ (Q) phase. Parts produced by this method could be applied in some engine parts like the cylinder sleeve, the piston valve retainer and monoblock [3]. There is a previous work about the characterization of Al-Si-Cu alloys [4] obtained by RSP using only one speed. However, the effects of RSP on structure at different tangential speeds when Mg is added are not reported. Beyond the analysis of second phase formation it is important to analyze the possible nanostructure formed in the alpha-aluminum phase, the most important characteristic for this kind of alloys, which directly affects the mechanical properties. Six melt-spun ribbons were produced with tangential speeds of 30 and 45 ms^{-1} changing the Mg content from 0.59 to 6.78 wt.%. The chilling surfaces (in contact with the rotating wheel) were characterized using high resolution transmission electron microscopy (HRTEM) using a FEG-Philips Tecnai F20 TEM operated at 200 kV. TEM bright field images of the melt-spinning ribbons at 30 ms^{-1} are depicted in Figure 1a-c. Figure 1a shows the microstructure of the alloy with 0.59 % Mg, consisting in the alpha-Al matrix and small Al_2Cu particles of approximately 20-50 nm in diameter. Figures 1(b,c) show small alpha-Al phase particles of approximately 10-30 nm in diameter for the alloys with 3.80 and 6.78 % Mg. Formation of nanosized alpha-Al particles for these alloys could be explained due to the presence of a higher quantity of alloying elements (higher Mg content), being favored heterogeneous nucleation. The presence of fcc-Al particles with a nearly spherical or an ellipsoidal morphology has been reported by Inoue et al. [5]. The analysis of the particles free zones of the matrices revealed the presence of nanostructures. As is observed in Figure 2a, small Al_2Cu nanocrystallites of approximately 2 nm in diameter are present in the α -Al matrix for the alloy with 0.59 % Mg. The obtained structure kind is similar to the one reported by Kim et al. [6] for other Al alloys. An image with several crystalline domains corresponding to Q phase can be clearly seen for the alloy with 3.80 % Mg, as is shown in Figure 2b. The size of this phase is in the range from 2 to 5 nm. The orientation appears to be random. Nanocrystallites of this phase also appear for the alloy with 6.78 % Mg. Conventional TEM image analysis for ribbons produced at 45 ms^{-1} do not reveal the presence of any second phase, suggesting the absence of any phase or that its size is under the resolution power of conventional TEM. For the alloy with 0.59 % Mg a nanostructure formed by nanosized fcc-aluminum particles and amorphous aluminum phase is observed in Figure 3a. No other phases were found. Alloys with 3.80 and 6.78 % Mg present Q nanosized particles in the amorphous matrix. This structural feature allows us to presume that the mixed structure is formed by the primary solidification of the amorphous phase, followed by the solidification of the remaining liquid as the fcc-Al phase or Q phase. Results show that for the studied Al-Si-Cu-Mg alloys was not possible to obtain a perfect solid solution even using the melt spinning technique, besides that the increase in speed origins the amorphization of the matrix, around which small crystalline phases solidified. The increase in Mg content in the alloys origins the formation of a higher quantity of nanoparticles due to the increase of the heterogeneity of the nucleation process. The use of HRTEM is indispensable for the complete image analysis of melt spun ribbons due to the nanometric size of the phases.

References

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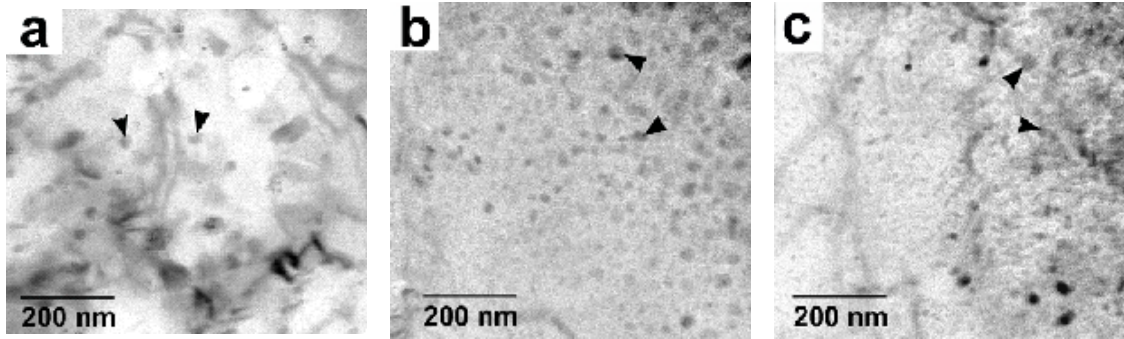


Figure 1. Bright field electron micrographs for alloys obtained at 30 ms^{-1} with: (a) 0.59 % Mg, [Al_2Cu arrowed] (b) 3.80 % Mg [$\alpha\text{-Al}$ particles arrowed] and (c) 6.78 % Mg [$\alpha\text{-Al}$ particles arrowed].

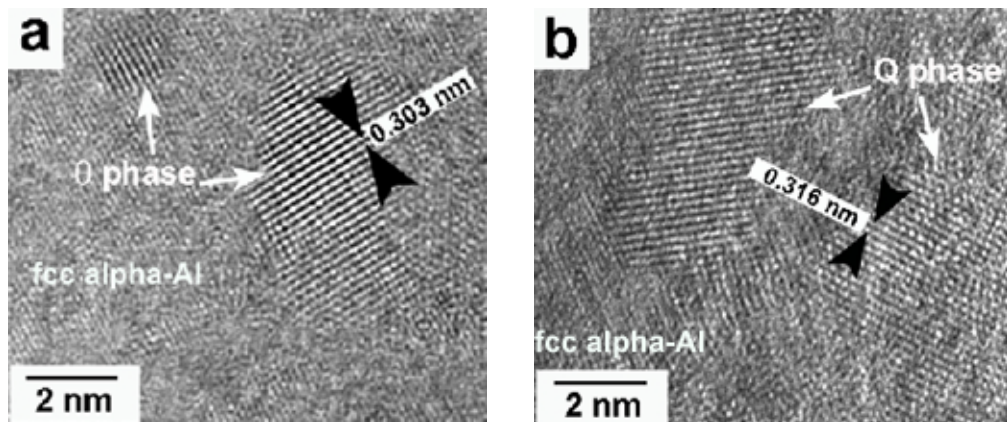


Figure 2. High-resolution images showing the presence of: (a) Al_2Cu for the alloy with 0.59 % Mg and (b) Q phase for the alloy with 3.80 % Mg for the alloys obtained at 30 ms^{-1} .

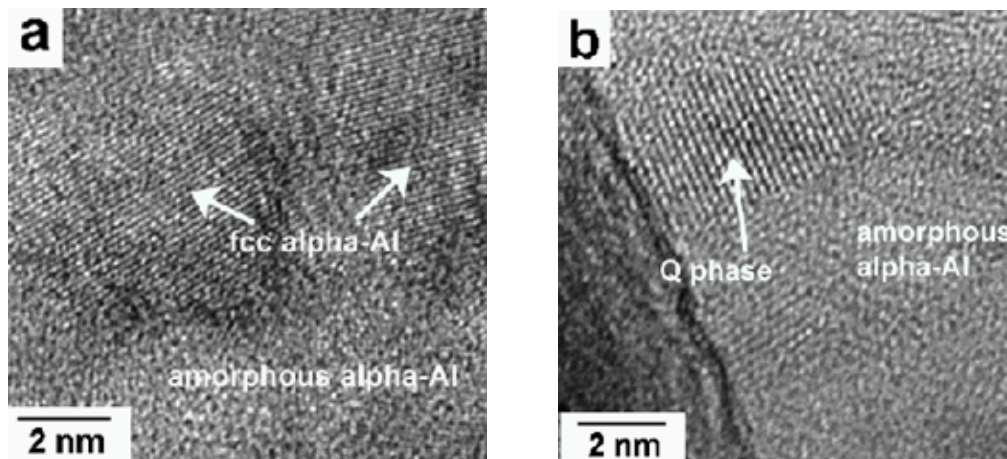


Figure 3. High-resolution images showing the presence of: (a) fcc $\alpha\text{-Al}$ for the alloy with 0.59 % Mg and (b) Q phase for the alloy with 3.80 % Mg for the alloys obtained at 45 ms^{-1} .