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Effect of 4 Wt% Magnesium on The Micro-hardness Of Aluminum Alloy Synthesized by Mechanical Milling

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Introduction

Light alloys have been used in the aerospace and automotive industry thanks to the excellent properties, high rigidity, mechanical strength, good corrosion resistance, and especially their low density, as well as low cost [1]. Which translates into associated energy benefits, that is, lower fuel consumption and a reduction in CO_2 emissions [2]. Mainly of aluminum alloys, are considered ideal for replacing steel in certain structural applications, due its low density. Several methods have been proposed and implemented to manufacture nano-crystalline light alloys, such as thermal spraying, powder metallurgy (PM), semi-solid powder processing, friction stirring process, flake powder metallurgy, extrusion of plasma by spark, mechanical milling (MA), among others [3-5]. Recently, mechanical milling has been used because enough energy is generated to allow the diffusion of atoms of the solute material in the solvent matrix, likewise, the dominant phenomena in mechanical milling allow the nanometric scale to be achieved. However, these high energies lead to the formation of second phases, sometimes these materials being undesirable. In recent years, the production of metal matrix composites using light alloys has been reported, with magnesium being the most manufactured. In this work, was analyzed the effect of 4% magnesium on the microhardness of an aluminum alloy synthesized by mechanical milling.

Methodology

For the manufacture of the Al-4wt% Mg alloy, were used (Sigma-Aldrich) micrometric aluminum and magnesium powders with a purity of 99.8% and 99.6% respectively. A planetary mill (RESTCH PM-100), with a ball-to-dust ratio (RPB) of 30:1, 3% by weight of stearic acid, as a process control agent to prevent the agglomeration of powders in the media milling and promotion cold welding. The powders were pressed at 516 MPa and sintered in a THERMOLYNE brand oven with a heating rate of 10 oC / min until reaching a temperature of 480 °C for 3 h, in an inert atmosphere of Ar gas. Subsequently, the obtained pills were roughed up with SiC sheets for the evaluation of microhardness. Microhardness was measured by applying a load of 1 kg, measurements in different areas. The structural characterization was carried out in the JEOL scanning electron microscope model JSM-7600F FEG-SEM, the BRUKER diffractometer model D8 advances with 40kV working.

Results

The matrix was synthesized by mechanical milling using a planetary mill. The milling was monitored to observe the change in morphology with an increase in milling time. Figure 1a presents the X-ray diffraction pattern for 0 h, the characteristic crystallographic planes of starting powders according to the jcpds card 991013095 attributed to an HCP crystalline structure from Mg and the jcpds card 991012829 attributed to a crystalline structure FCC from Al. With the increase of the milling time 6-18 h, the decrease of the Mg planes is observed until 24 h, where the solute peaks disappear completely; this indicates that the solid solution has been carried out.

Figure 1b shows the variation of the lattice parameter with the milling time, it is appreciated that in 6 h there is a significant increase in the value. With the increase in grinding (12-18 h), it is observed that the parameter continues to increase, tends to expand the crystalline network of Al, until 24 h where the

parameter remains constant, suggesting that Mg has completely entered the Al lattice. The analysis of the phase quantification confirms the results of the lattice parameter, where at 6 h, the largest amount of Mg in the Al lattice [6].

The milling powders were analyzed by MEB, starting from a size of 1 mm. Figure 2a shows that at 6 h, the particles decrease in size due to the phenomenon of fracture. Figure 2b shows that within 24 hours of the process, the powders have decreased in size to 10 µm products of the dominant phenomena in milling [7]. Figure 2c shows HR-TEM image with an interplanar distance of 2.33 Å, corresponding to the plane (111) of a crystallographic structure FCC of Al. Figure 2d illustrates the tablet after the sintering process, consolidated regions are appreciated, due to diffusion between particles which reduces porosity [8]. Figure 2e shows lengths of 152.9 µm for indentation marks, resulting in a microhardness value of 62 ± 2 HV, due to the good consolidation of the material in the sintering process. Figure 2f shows the EDS analysis shows the elements present are Al, Mg, and O product slight surface oxidation. Aluminum has a microhardness of 22 HV [9]; in this work, an increase in microhardness was obtained due mainly to the addition of Mg, which generates a strain hardening.

Conclusions

In this work it was possible to form a nanostructured alloy of Al-4% Mg in 24 h, through the use of planetary mechanical grinding and RPB of 30: 1. The formation of a second phase that could be detrimental to the composite was avoided. The processing route made it possible to obtain an increase in the microhardness of the consolidated material, with which we conclude that Mg has a positive influence on Al microhardness.

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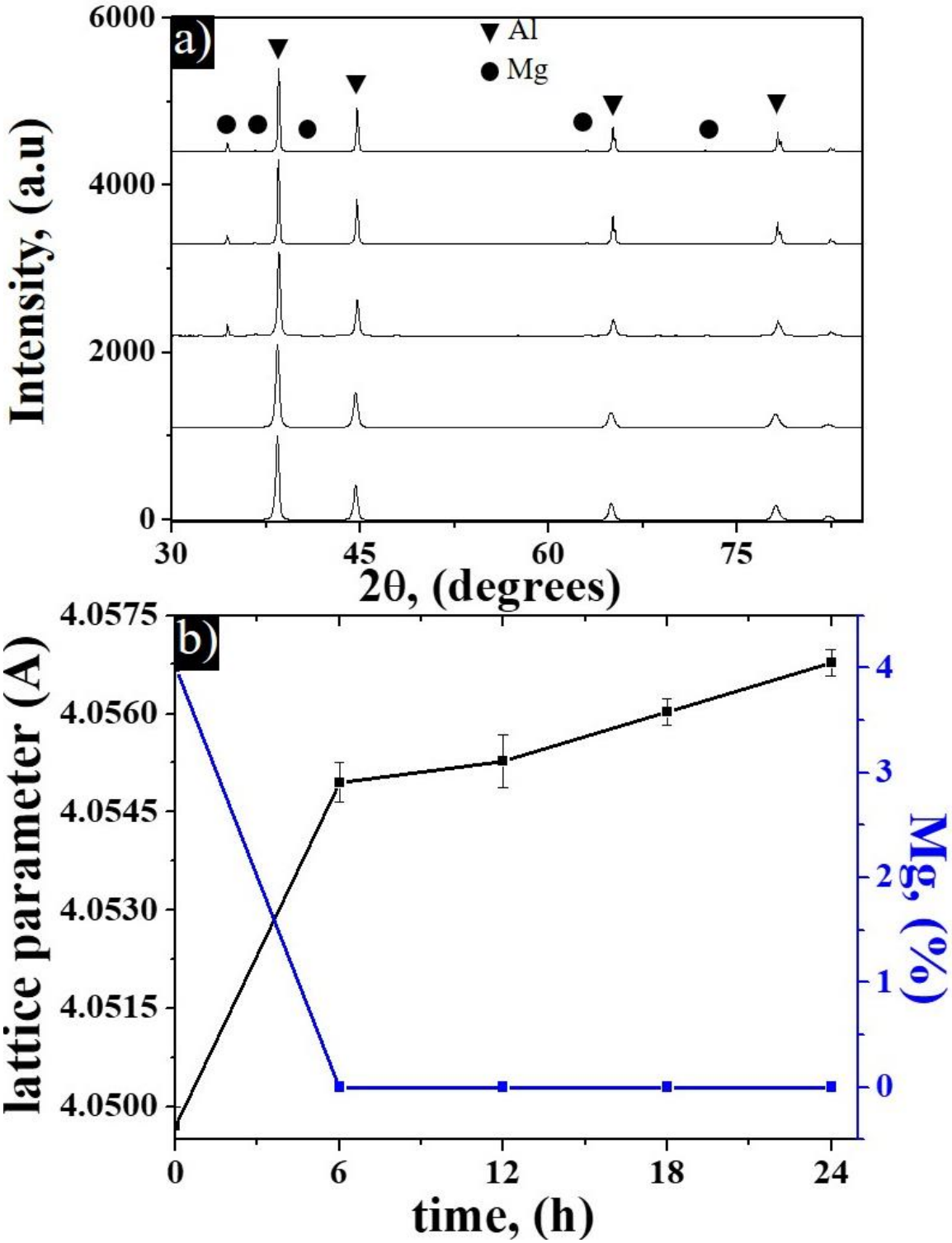

Figure 1. Analysis by XRD, a) milling time of Al-4wt% Mg alloy, b) lattice parameter, and phase quantification.

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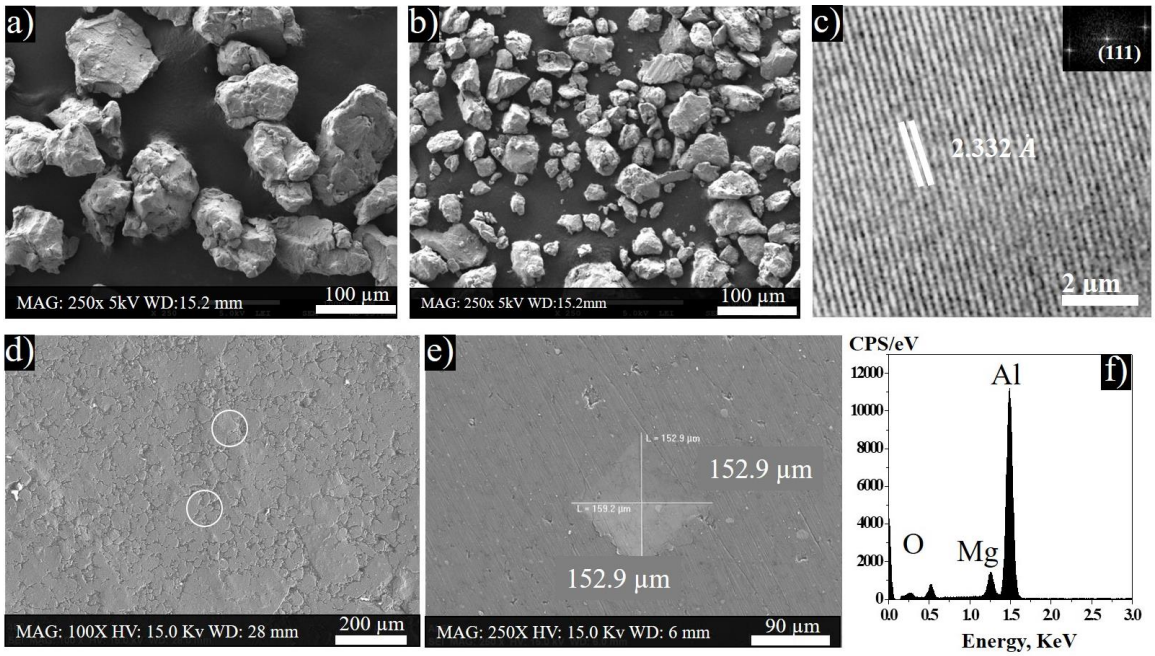

Figure 2. Analysis of Al-Mg powders 4% weight a-b) different milling times, c) HR-TEM image, d) sintered tablets micrographs, e) Vickers microhardness test, and f) EDS analysis.

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