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Dynamic Precipitation in Al-4Cu and Al-4Cu-4Mg Cold-rolled Alloys

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Al-Cu-Mg alloys are the most important of the 2xxx series, and these are widely used in the aerospace industry and transportation. Properties of these alloys are controlled mainly by interactions between the dislocations and precipitates (precipitation-hardening) [1-5]. On the other hand, dynamic precipitation is a phenomenon through which nanometric precipitates are produced in the crystalline grain's interior derived from a severe plastic deformation process. Compared to static precipitation, dynamic precipitation requires less time and occurs at low temperatures due to the rapid diffusion velocity of the solute atom in the aluminum matrix [6]. Dynamic precipitation has been observed in some alloys not-hardenable by the aging treatment that have been subjected to severe plastic deformation [1,7]. However, dynamic precipitation has not been reported in Al-Cu-Mg alloy systems deformed by cold-rolling. Thus, this study evaluates the effect of plastic deformation by cold rolling on the dynamic precipitation mechanism and its influence on the hardness in the Al-4Cu and Al-4Cu-4Mg alloy systems.

Al-4Cu and Al-4Cu-4Mg alloy systems were obtained by casting in a LINDBERG BLUE electric furnace at 740º C. Molten alloys degassing were carried out argon gas flow and a graphite helix at 490 rpm rotation velocity for 5 min. Besides, 0.33 gr of Al-5Ti-1B as grain refiner was added. The melted alloys were poured on preheated molds at 260º C and after extruded at 495º C. The obtained bars were solubilized at 510º C for 5 hours and quenching in room temperature water (Solution Heat Treatment-SHT). Posteriorly, extruded samples were deformed by cold-rolling to obtain a 50% reduction with roller rotation at 60 rpm speeds. Samples of 20 mm length were sectioned to carry out the thermal aging treatments at 195º C for 30, 60, 300, 600, 3000, and 6000 min. Microstructural characterization was carried out by X-Ray with a Panalytical X'Pert PRO diffractometer and scanning electron microscopy (SEM) using a Hitachi model SU3500. The mechanical behavior was evaluated by Vickers microhardness with a LECO LM300AT tester with a 50g charge and 10s time.

Figure 1 shows X-Ray patterns corresponding to Al-4Cu (a) and Al-4Cu-4Mg (b) alloys. It can be observed that after the SHT, all intermetallic compounds (AlCu, Al_2Cu, and Al_2CuMg) generated during the casting process have been dissolved on both alloys. After plastic deformation, characteristic peaks of the Al_2Cu phase can be observed on Al-4Cu alloy patterns. Similarly, peaks corresponding to the Al_2CuMg phase can be observed on Al-4Cu-4Mg alloy patterns. Hardening of the alloys is presented in figure 1c; an increase in the hardness of the alloys (46%) after plastic deformation can be observed. The hardness values for Al-4Cu increased from 102 HV for the solubilized sample to 149HV in those that were plastically deformed, showing no response to the aging heat treatment. For Al-4Cu-4Mg alloy, the hardness increases from 156HV in the solubilized sample to 228HV in the plastically deformed one to reach a maximum hardness during the aging heat treatment 252HV 60min after starting.

Figure 2 shows the microstructure of the processed alloys, formed by dendrites of irregular morphology with an interdendritic phase, which can be seen in both samples since copper is preferentially segregated towards the interdendritic, and magnesium is distributed in a more homogeneous. This behavior is due to the ability of each of the alloying elements to dissolve in the aluminum matrix. Figures 2c show the effect of SHT on the microstructure of the alloys studied. The presence of the initially interdendritic phase becomes a dispersion of a second phase, in less quantity, which also maintains the direction in which the samples were extruded.

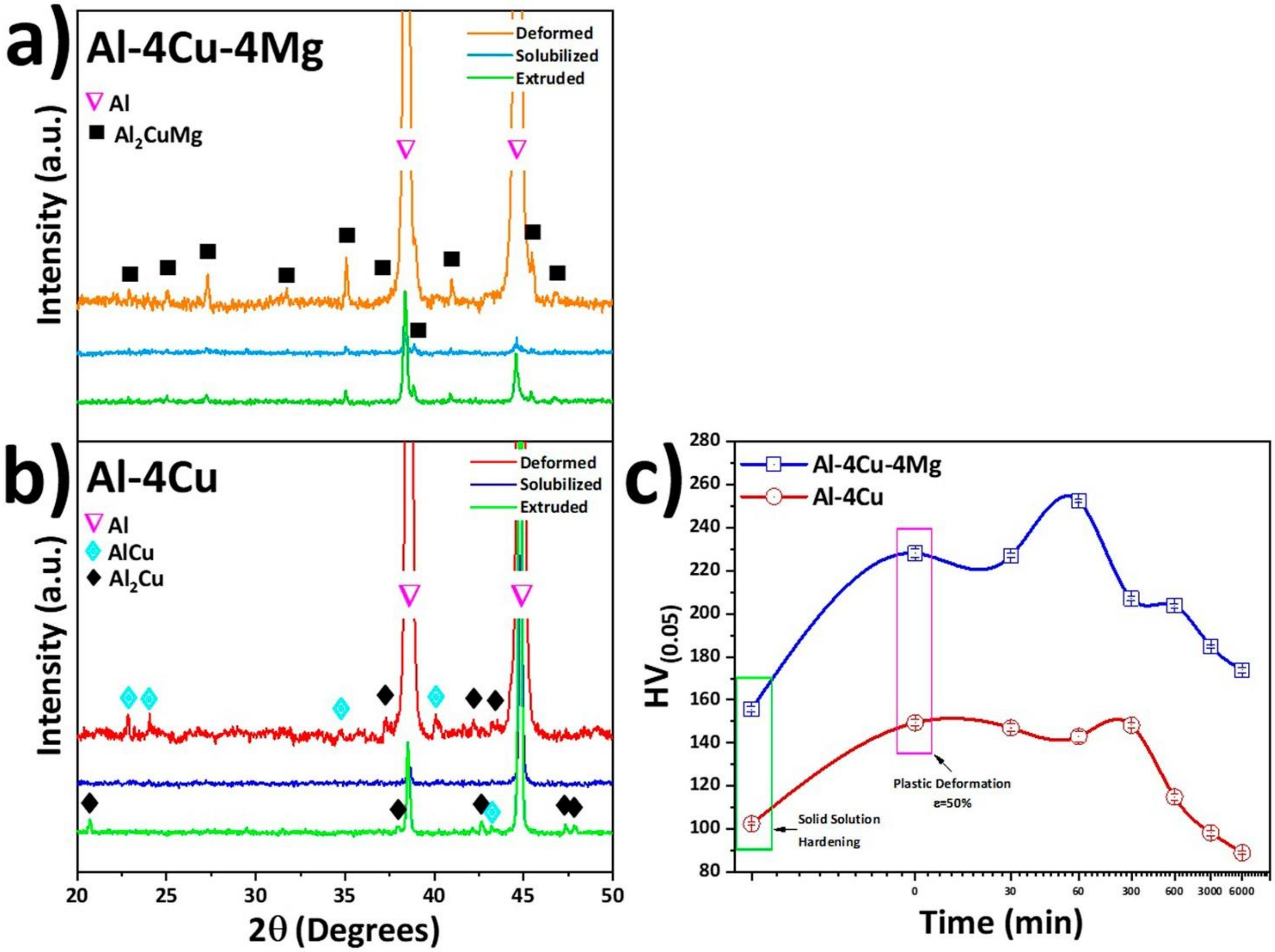

Figure 1. X-ray diffraction of the alloys (a) Al-4Cu-4Mg and (b) Al-4Cu. (c) Hardening of the alloys after the solution treatment, plastic deformation and evolution of the aging treatment.

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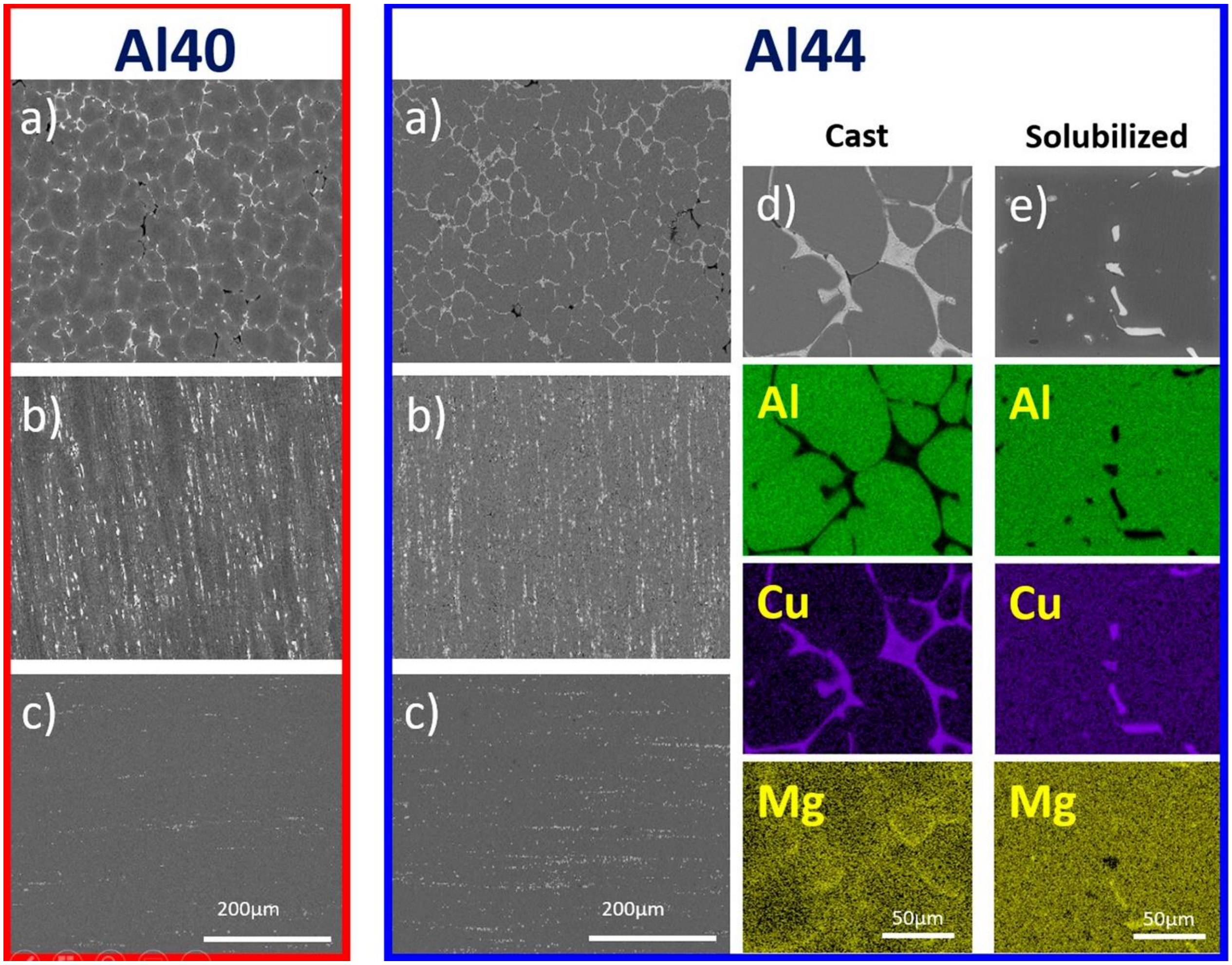

Figure 2. Micrographs of the Al-4Cu (Al40) and Al-4Cu-4Mg (Al44) alloys in (a) Cast, (b) Extruded and (c) Solubilized conditions. SEM-EDS elemental mapping of alloy A44 in the state of d) cast and e) solubilized.

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