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Dispersion of CNTs into an Aerospace-Grade Aluminum Alloy

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The synthesis of composite materials presents a unique opportunity for the study and development of advanced materials with properties of interest to the scientific community and with results that can be applied and used by different industries in order to improve their competitiveness [1, 2]. In recent years, the aerospace industry has shown a growing demand for advances related to the development of new materials for the manufacture of various components, which require improved performance under different temperature and load conditions [3].

Even though aluminum and its alloys were widely used until the mid-1980s, their use in the aerospace industry has decreased due to the presence of ceramic or polymer-based composite materials as lightweight alternatives to metals. However, the development of aluminum-based composite materials, has allowed in public and private institutions the study of the effect of reinforcing materials of a micro and nanometric nature related with their use in the improvement of the mechanical performance of this group of light alloys [4, 5].

In this work, carbon nanotubes (CNTs) and the aerospace-grade 2024 aluminum alloy, obtained from machining process in form of metal chips, were placed in a vial, in order to be milled during 5 hours. The vial was made from hardened steel (D2) and the milling media was made from stainless steel. The synthesis of composite materials by mechanical alloying was performed using a Spex 8000 high-energy mill. CNTs were added in a concentration of 5.0 wt.%. The powder mass was 8.5 g and the ball to powder ratio was 5:1. Metal powders were cold-consolidated and sintering during 2 h at 500 °C. Solution heat treatments and artificial aging were carried out on the sintered composites. The solution temperature was of 490˚C, and artificial aged at 190˚C, with respective aging times from 2 to 24 h. The microstructural characterization was carried out in the as-milled powders in order to observe the CNT effect in their particle size. X-ray analyzes were carried out on the heat treated composites in order to observe the chemical stability of the composites as function of different aging conditions.

Fig. 1a presents a schematic representation of the processing synthesis employed in this study. The as-milled powders (Figs. 1 b, c) are displayed by secondary electron SEM images showing the effect of CNTs (Fig. 1d) on particle size for a fixed milling time. It is observed that the CNTs provide a refining effect on the particle size of the composite. Fig. 1 e,f shows a series of X-ray diffraction patterns as a function of aging time for the unreinforced sample (Fig. 1e) and the sample reinforced with 5.0 wt.% of CNTs (Fig. 1f). The X-ray diffraction pattern of a composite is affected by several reasons, among of them are the processing conditions, the addition of alloying elements and the temperatures at which a material is thermally treated. The diffraction pattern observed in Fig. 1 e,f shows minimal changes in the height and width of the peaks. Depending on the aging time, a change in the peaks broadening is not observed, which indicates a minimal presence of micro strains and residual stresses remaining in the samples. In both cases, the presence of the Al_2Cu phase is observed, characteristic of the Al2024 alloy, since copper is its main alloying element.

The presence of CNTs in the aluminum alloy is rapidly observed by the formation of a hard phase, identified as aluminum carbide (Al_4C_3), which is the product of the chemical interaction between the CNTs and the aluminum matrix [5,6]. It is observed that despite the use of 5.0 wt.% of CNTs, the peak corresponding to carbon signal is not visible in the diffraction pattern of sample displayed in Fig. 1f at their different heat treated conditions. This is due to the limitations of the X-ray diffraction technique, to low concentrations of reinforcing material or in a solution or homogeneous dispersion of particles in the matrix of the analyzed material.

The mechanical processing of aerospace-grade aluminum alloy powders modified with CNTs, includes numerous events of cold welding and fracture. Composite materials manufactured through this technique exhibit interesting properties that represents an attractive method for the production of powdered feed sources, for the manufacture of components by means of additive manufacturing techniques.

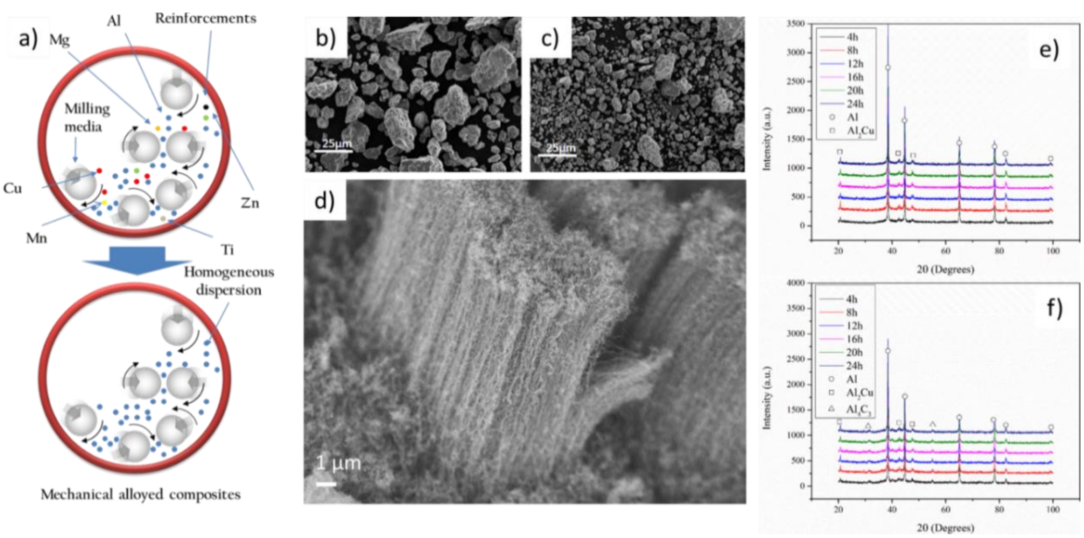

Figure 1. (a) Schematic process of mechanical alloying. (b, c), SEM micrographs of the as-milled Al2024 and the CNT/Al2024 powders (d) CNTs, (e,f) XRD results of the Al2024 and CNT/Al2024 heat treated samples as function of aging time.

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