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Synthesis and Characterization of Al Reinforced with Al_4C_3 Nanoparticles Produced by Mechanical Milling

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Mechanical alloying technique, such high energy ball milling process, is suitable for producing composite metal powders with a fine controlled microstructure. This method is crucial for obtaining homogeneous distribution of nano-sized dispersoids in a more ductile matrix (e.g. aluminium- or copper based alloys). The reinforcing particles Al4C3 have become an interesting reinforcing material because their high level of physical and mechanical properties, e.g. high temperature strength, thermal cyclic resistance, wear resistance and low linear expansion coefficient. Therefore, the reinforcement of the aluminum using Al_4C_3 has recently become the subject of many studies and widely used for products and structures [1, 2].

The Al-based composites were produced by mixing Al powder (99.5 % purity) with 1 and 2 wt. % of Al_4C_3 nanoparticle powder (previously synthetized by mechanical milling and subsequent heat treatment), each Al-Al_4C_3 mixtures powder were mechanically milled in a high energy Simoloyer mill during 8 h. Argon was used as the milling atmosphere and ~4 ml methanol as a process-control agent. The device and milling media used were made from hardened steel. The milling ball to powder weight ratio was set to 50:1. Consolidated samples were obtained by pressing the powder mixtures during 20 s at 350 MPa in uniaxial load. The consolidate sample was sintered during 2h at 650°C. The Al4C3 reinforcing phase dispersed into the aluminum matrix also was observed by using electron microscopy analyses.

Fig. 1a shows a STEM bright-field image of Al-20 sample (2 wt. % of Al_4C_3 and not sintered), the image shows a graphite nanoparticle of about 10 nm long which is close to an Al4C3 nanoparticle that shows an irregular shape present in the aluminum matrix. Fig. 1b shows the simulated image that shows the interplanar distance of the A selected area of a Al_4C_3 nanoparticle and the interplanar distance of the B selected area of a graphite nanoparticle. The Fig. 2a shows a STEM bright-field representative image of a rod-shaped aluminum carbide nanoparticle of about 100 nm long and 10 nm wide in the Al matrix of Al-22 sample (2 wt. % of Al_4C_3 and sintered during 2 h). The HRTEM image of Figure 2b shows the interplanar distances of a rod shaped particle which correspond to Al_4C_3 compound. At seems the Al_4C_3 irregular shape nanoparticles dispersed into the Al matrix during the mechanical milling change to a regular rod-shaped after the sintering process.

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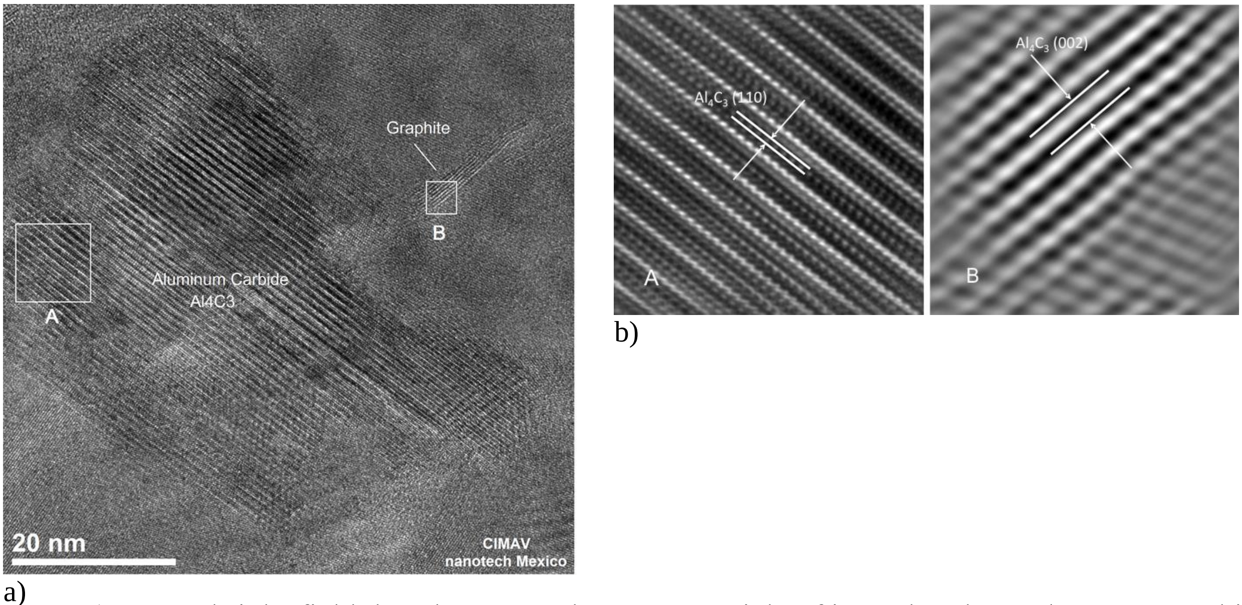

Figure 1. a) STEM bright-field that shows an Al_4C_3 nanoparticle of irregular-shape close to a graphite nanoparticle in the Al matrix of the Al-20 sample. b) Simulated image that shows the interplanar distance of the A selected area of a Al_4C_3 nanoparticle and the interplanar distance of the B selected area of a graphite nanoparticle.

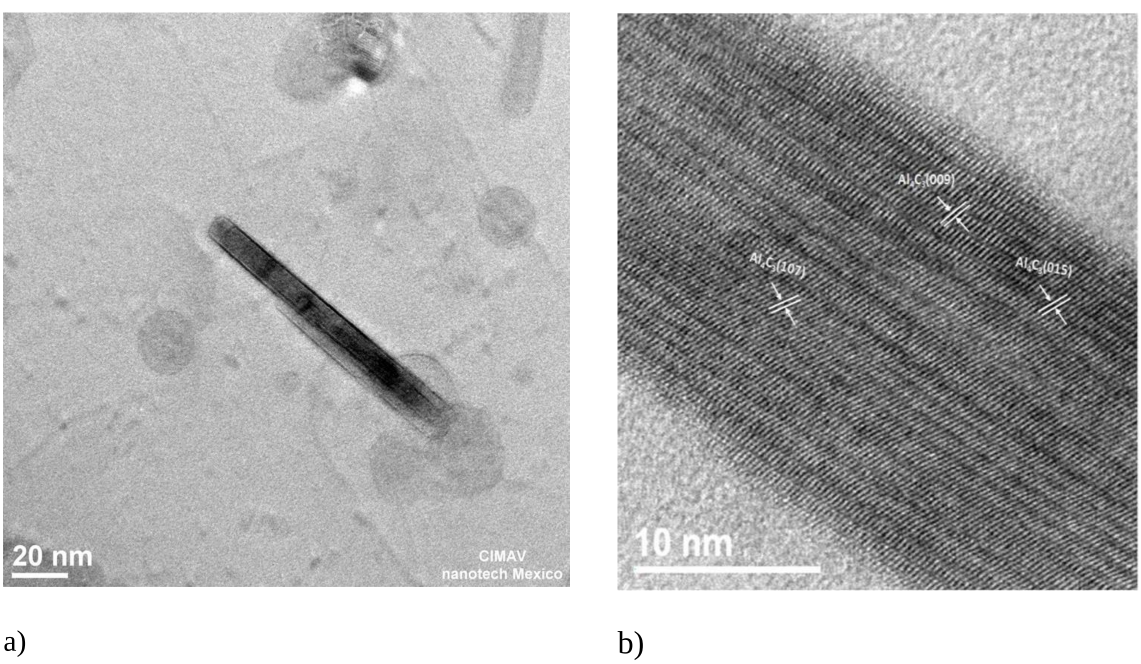

Figure 2. a) SEM image of the Al-14 sample that shows the crystallites coalescence induced by the sintering process. b) HRTEM image that shows the interplanar distances of the Al4C3 compound.

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