

Nano-Sized Silicon Dioxide Reinforced Aluminum Alloy 2024-T6

C. Carreño-Gallardo¹, I. Estrada-Guel¹, C. Leyva-Porras¹, C. López-Meléndez² and R. Martínez-Sánchez¹

¹ Centro de Investigación en Materiales Avanzados (CIMAV), Laboratorio Nacional de Nanotecnología-Chihuahua. Miguel de Cervantes No. 120, CP 31109. Chihuahua, México

² Universidad La Salle Chihuahua, Prol. Lomas de Majalca No. 11201, C.P. 31020 Chihuahua, México

The increasing demand for weight reduction and low fuel consumption in structural applications, particularly aerospace and automotive industries has had a marked effect on the judicious selection of materials. There has been a great upsurge in using aluminum alloys, the attractive physical and mechanical properties that can be obtained with MMC including high specific modulus, superior strength, long fatigue life, and improved thermal stability, which leads to the weight reduction resulting in a considerable economic advantage [1, 2]. MMC consists of a metallic base with a reinforcing constituent, usually ceramic. Commonly, micro-ceramic particles are used to improve the yield and ultimate strength of the metal. However, the ductility of the MMC be deteriorated with high ceramic particle concentration. It is of interest to use nano-sized ceramic particles to strengthen the metal matrix, so-called metal matrix nano-composite (MMC), while maintaining good ductility [3].

The aim of this research was study the effect of the SiO₂ NP nanoparticle dispersion by milling process and its effect over the mechanical properties and microstructural evolution during T6 temper, by using aluminum alloy 2024 based composites.

The raw material used in this study was Al₂₀₂₄ commercial alloy and silicon oxide (SiO₂) particles which was synthesized according to Stober's method [4]; tetraethylorthosilicate (TEOS) reacted with water (H₂O) and ammonium hydroxide (NH₃OH) in an alcoholic medium. After washing and drying the particles, these were observed in the microscope. A spherical shape with a narrow size distribution and an amorphous microstructure was found. The chemical composition of Al₂₀₂₄ is shown in Table 1.

The Al₂₀₂₄ powder was produced by machining a solid extruded bar. The machined metal febris were mixed with SiO₂ NP in different concentrations (0.00, 0.50, 1.00, 1.50, 2.00, 2.50, 5.00 and 7.00 wt. % SiO₂NP). Mixtures were mechanically milled in a high- energy ball mill SPEX8000 under argon atmosphere. Milling products were cold consolidated at 330 MPa by a cylindrical steel die (compacting device) in order to obtain samples with 5 mm of diameter and 10 mm high. Green products were pressure-less sintered for 3 h at 500°C.

After sintering, the specimens were put to the test upon heat treated solution for 1h at 495°C and quenching in room temperature water. Then, samples were artificially aged (T6 Temper) for 12 h at 191°C.

Figure 1 shows the behavior of hardness for 2h of milling time, a considerable difference can be appreciated between mechanical milling conditios (green) and T6 condition, where 1.5% SiO₂NP composite in T6 condition show the highest hardness value.

There is an appreciable hardness saturation value of 98.26 HRF at 1.5% SiO₂NP concentration. At higher NP concentrations only a slight decrease in the hardness values was observed.

Figure 2 shows the morphology and size of SiO₂NP, which were employed as reinforcing material of aluminum alloy 2024. The average of the size was 60nm.

SiO₂NP can be incorporated into Al₂₀₂₄ matrix uniformly by milling process, AA2024-1.5 wt. % SiO₂NP composites showed the best mechanical properties and several strengthening mechanisms contributed in order to reach the outcomes.

References:

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 [3] K. Akio, O. Atsushi, K. Toshiro, T. Hiroyuki, J. Jpn. Inst. Light Met. **49** (1999) 149–154.
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Table 1. Composition of the Al₂₀₂₄ used (wt.%) in this work.

Al	Cr	Cu	Fe	Mg	Mn	Si
Bal.	0.038	4.004	0.246	0.876	0.673	0.128

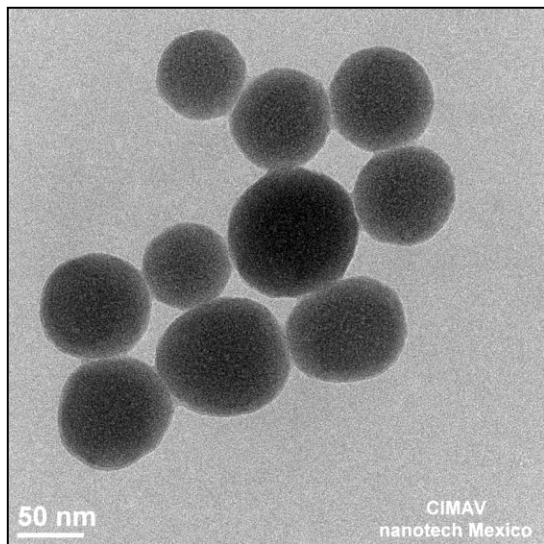


Figure 1. Micrograph from SiO₂ nanoparticles.

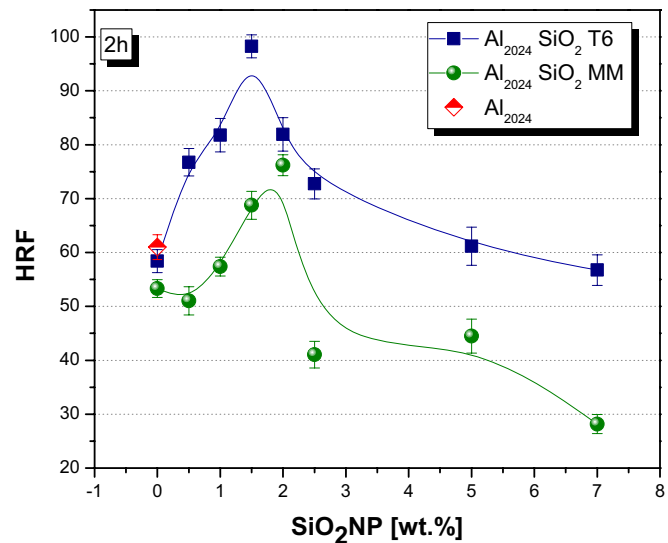


Figure 2. Hardness as a function of nano-SiC particles weight fraction