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Novel Composites Aluminum-Multi-Walled Carbon Nano-Tubes

R. Martínez-Sánchez*, I. Estrada-Guel*, M. Miki-Yoshida*, W. Antúnez-Flores*, A. Santos-Beltrán* and I. Barajas-Villaruel**

* Centro de Investigación en Materiales Avanzados (CIMAV), Miguel de Cervantes No.120, C.P. 31109, Chihuahua, Chih., México.
** Universidad Autónoma de San Luis Potosí, Álvaro Obregón No. 64, C.P. 78000, San Luis Potosí, S.L.P., México.

The need to increase the mechanical properties in aluminum alloys has motivated the study of new materials and innovative routes to prepare them. Aluminum-based Metal Matrix Composites (MMC), are demanded because of their low density and high specific stiffness. These materials can be produced by dispersing reinforcement particles (in form of oxide, carbide or nitride) into metallic matrix. However, a new kind of reinforcement material is raising the interest into the scientific community, the Carbon NanoTubes (CNT), which can include single and multi walled carbon nanotubes. The excellent mechanical properties and chemical stability, suggest that the CNT might be suitable as a novel fiber material for MMC. However, very few experimental works using CNT as a composite reinforcement have been reported in the literature. Additionally, there are not reports about CNT reinforcing aluminum composites produced by Mechanical Alloying or Mechanical Milling. Thus, a new type of composites is emerging by combining two apparently immiscible phases: Aluminum matrix and CNT by using far from equilibrium process.

Al (99.9 % pure, -200 mesh in size) and Carbon NanoTubes were used as raw materials, to produce the microcomposites Al- CNT. CNT were produced by the spray pyrolysis method. Different compositions of microcomposites were studied. Each mixture was mechanically milled in a high-energy shaker mill (SPEX-8000M) at different milling times. Ar was used as milling atmosphere.

Figure 1 shows a SEM micrograph from fractured surface in Aluminum-based composite in the as-sintered condition, showing the CNT dispersed into Aluminum matrix. CNT are dispersed homogeneously and at random into the Aluminum matrix. These CNT are responsible of the excellent mechanical properties as we will show below. In conventional Carbon Fiber/Aluminum composites, Aluminum Carbide (Al_4C_3) usually growths on the prismatic planes of the Carbon Fiber; contrary to conventional Carbon Fiber/Aluminum composites, in our case, no carbide was observed at the interfaces CNT/Aluminum; this could be a result of the excellent chemical stability of the CNT.

Figure 2 shows the compression test results obtained in the microcomposites in the sintered condition. The important effect of milling time is evident. Apparently for 1 h of milling time, the composition effect is not very important, giving a variation of σ_y from ~12 Kg/mm^2 to ~14 Kg/mm^2. However for 2 h of milling time σ_y increases as the CNT concentration increase as well. It is notice that with only 0.75 % of CNT the yield strength was increased in about 60 %. The hardness of the CNT-Aluminum microcomposites at different concentrations is also shown in Table I. An increase in the hardness produced by the nanocrystalline state is evident in pure Aluminum; these values should also be compared with those values reported for bulk aluminum in as-annealed condition (15 HV).

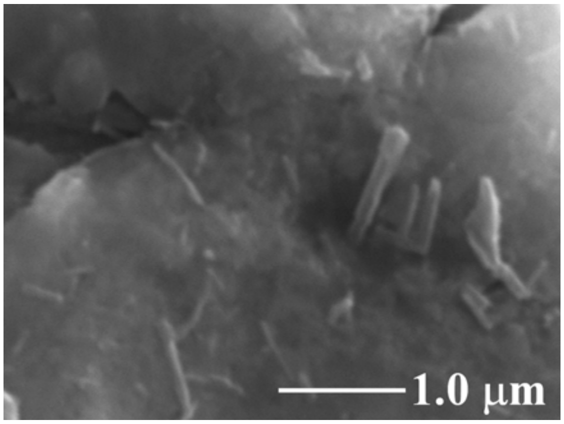

Figure 1.- SEM micrograph from aluminum-based microcomposite in the as-sintered condition.

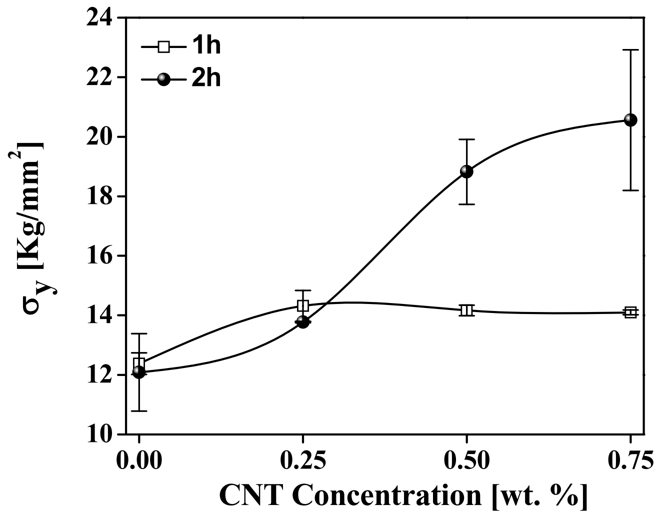

Figure 2.- Yield strength in microcomposites as a function of CNT content.

Table I.- Yield strength, Maximum strength and Vickers hardness values obtained in microcomposites aluminum-based

	Comp.	σ_y [Kg/mm^2]	σ_{max} at $\varepsilon = 0.3$ [Kg/mm^2]	Vickers Hardness
1 h	0.00	12.378	21.320	56.5 ± 2.2
	0.25	14.312	21.184	51.4 ± 1.7
	0.50	14.155	21.630	64.2 ± 1.8
	0.75	14.100	23.181	69.1 ± 2.3
2 h	0.00	12.089	22.801	43.0 ± 1.4
	0.25	13.782	24.486	52.1 ± 2.5
	0.50	18.825	29.030	75.5 ± 1.3
	0.75	20.574	35.604	76.6 ± 4.3

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