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Exploring the Reinforcing Effect of Ag_cNP and Al_2O_3NP in Aluminum Alloy 2024 Matrix Composites

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Carbon coated silver nanoparticles are a promising material for different applications, such as strengthening of particulate metal matrix composites [1-3]. At the same time, the development of new, advanced materials, including nanomaterials and metal matrix composites with nanoscale reinforcing particles, has been a focus of ongoing research to increase the quality and the service life of various products.

The focus of this work is the formation of 2024 aluminum alloy (Al_{2024}) as well as the dispersion of NP (Al_2O_3NP and Ag_CNP) by mechanical alloying process (MA). There are several works related to the dispersion of hard particles, but about the ductile particle dispersion, works are scarce or inexistent. The effect of two different kinds of nanoparticles (Al_2O_3NP and Ag_CNP) nanoparticles on the mechanical resistance of an aluminum alloy is characterized. Carbon shell helps to avoid the dissolution of silver into the aluminum matrix. Microstructural characterization as a function of milling time and nature of NP is presented.

The raw materials were elemental powder (Al, Cu, Mg, Mn, Si and Fe), alumina nanoparticles (Al_2O_3NP) and carbon-coated silver nanoparticles (Ag_CNP). Elemental powders were mixed in the correct proportion to form the Al_{2024}. MA is the milling process used to produce the Al_{2024} and the composites materials. Different concentrations of NP were dispersed into Al_{2024} matrix, Table 1 shows the different compositions used.

The Figures 1a show the microhardness value in composites as a function of milling time and content of NP. A direct relationship of hardness with NP is observed. As the weight percent of NP is increased, the hardness increases as well.

In this work, there is an additional reinforcement effect of alloying elements; which will still having effect because the new phases formation during thermal treatment or thermomechanical process. Because Al_{2024} is prone to strengthened by precipitation heat treatment (T6), it is expected that NP will have an additional and important effect over the mechanical properties after T6-temper.
Figure 1b shows previous results in hardness test after heat treatment in composites. It is expected that solution treatment in powders, will decrease the mechanical properties. However, the subsequent precipitation treatment increase the mechanical resistance over the values reported for milled products. It is observed that with longer milling time have better results are observed.

Fig. 2 shows a TEM image and EDS of the as-milled Al_{2024}–1 wt.% Ag_CNP sample. Fig. 2 shows conventional TEM images of the Al sample with 1% of Ag_CNP. The contrast corresponds to bend contours, grain boundaries and dislocations. The grain size of the Al-based matrix is the range 30–200 nm.

The nanometric size of Al_2O_3NP and Ag_CNP makes not possible their identification by XRD, so further studies by transmission electron microscopy are necessary for better identification and characterization in terms of morphology, size and distribution. The solid solution formed by milling is decomposed to equilibrium phases (Al, Al_2Cu and Al_2CuMg) upon heating. The NP effect on microhardness is observed from the lowest NP concentrations.

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Table 1. Kind and concentration of nanoparticles reinforcement used in this work.

Matrix	***Reinforcement agent***	***Concentration [wt.%]***						
Al_{2024}	Al_2O_3NP	0.0	0.5	1.0	1.5	2.0	2.5	3.0
	Ag_CNP	0.0	0.5	1.0	1.5	2.0	2.5	3.0

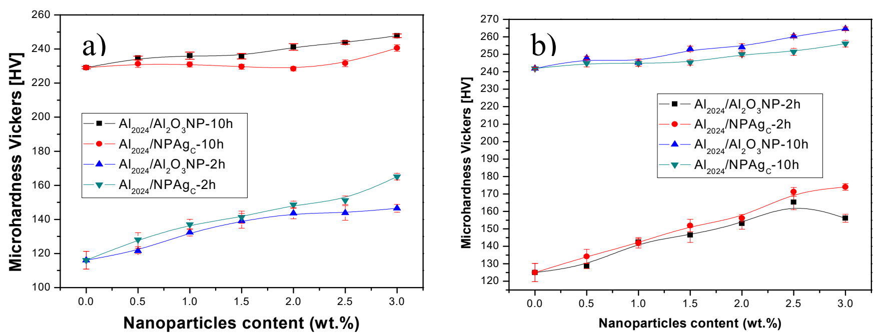

Figure 1. Effect of NP content and milling time on microhardness values, Al_2O_3NP and Ag_CNP (a), and the hardness results after heat treatment and effect of NP content and milling time (b).

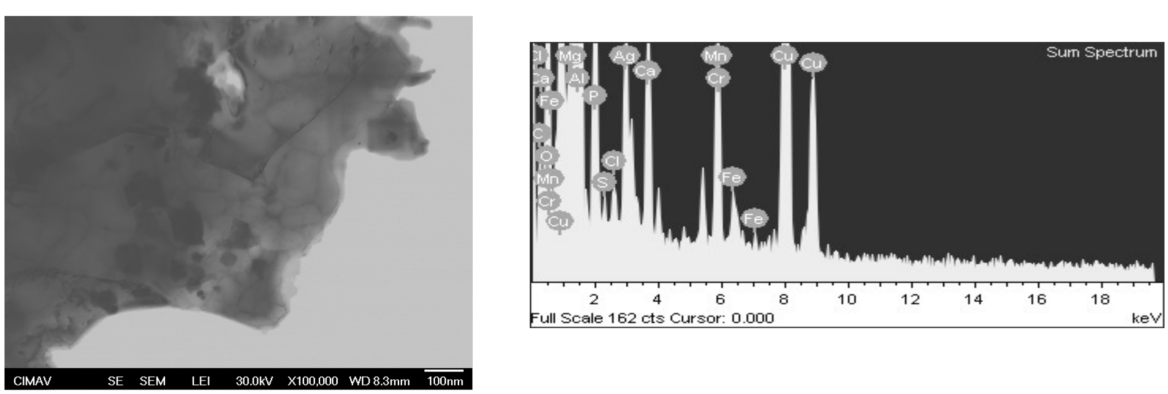

Figure 2. TEM micrograph shows the Ag_CNP into the matrix aluminum alloy 2024 and EDS analyses.

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