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Al_4C_3/Ag Formation in an Aluminum Composite Produced by High-Energy Ball Milling.

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Aluminum and its alloys have a lot of industrial applications due to their appropriate physical and chemical characteristics. However, those present a modest mechanical performance. One method to improve its strenght is the addition of hard insoluble particles as: carbides (Al_4C_3, TiC), oxides (Al_2O_3) or nitrides (TiN, AlN), which can difficult the dislocation movement at atomic level, resulting in material reinforcement. The couple aluminum/graphite shows a reactivity increment with temperature, causing the formation of aluminum carbide according to the chemical reaction [1]:

$$4Al_{(l)} + 3C_{(s)} \rightarrow Al_4C_{3(s)}$$

The existence of this phase increases the mechanical properties of the material due to its small particle size (100 nm) and high hardness (1000-1400 HV) [3]. Has been reported that the composites with binary reinforcements exhibits higher strength compared with single reinforcement acting alone [2]. Flores et al. found a reinforcement effect in aluminum by adding silver nanoparticles coated with carbon, this carbon shell avoid silver dissolution into Al matrix and arrest the dislocations movement [3].

The present work deals with the synthesis of Graphite/Silver (CAg) composites Aluminum based by high-energy milling and the evaluation of milling intensity on structure and mechanical response of the prepared composite. Raw materials were: natural Gr flakes, Al and Ag in powder form. Gr/Ag powder mixtures (10 at. % Ag) were produced by milling in a high-energy SPEX 8000M device, using a 5:1 rate (milling media: sample) for 0, 1, 2, 4 and 8h periods. The next step was adding milled Gr/Ag particles to the Al matrix (1.0 wt. %) and mill for 2h. The milled powders were cold compacted (900 MPa) in order to obtain cylinders (6.75 mm of diameter and 13.5 mm long) and sintered at 623K for 4h in an Ar atmosphere to get samples for mechanical characterization.

The mechanical tests were carried out with an Instron machine model 4468 (by triplicate). The morphology, size and distribution of the reinforcements were observed by TEM in a model JEM2200-FS, films were prepared with a FIB-JEM9320.

Fig. 1 exhibits some TEM micrographs where is observed a high amount of aluminum carbides surrounded by bright zones. Using elemental analysis and line scan it is noticeable the presence of silver, indicating that this element is present in the Al4C3 cylinders.

The Fig. 2 shows the compressive curves obtained from 2h milled Al composites with reinforcing particles compared with a blank without reinforcement (milled and unmilled); it is evident an increment in the yield strength caused by the addition of Gr/Ag particles. The milled Al sample presents a superior mechanical performance compared with unmilled sample, due to cold work and high internal stress caused by the increment of dislocation density and grain refinement provoked by milling [4].

References:
[1] T. Etter, P. Schulz, M. Weber, Mat. Sci. Eng. A **448** 2007 p. 1-6.
[2] S. Suresha and B.K. Sridhara, Mat. Design **34** 2012 p. 576-583.
[3] R. Flores-Campos, I. Estrada-Guel, M. Miki-Yoshida, Mat. Characterization **63** 2012 p. 39-46.
[4] This research was supported by CONACYT (Project No. 169262) and the Redes Temáticas de Nanociencias y Nanotecnología (124886).

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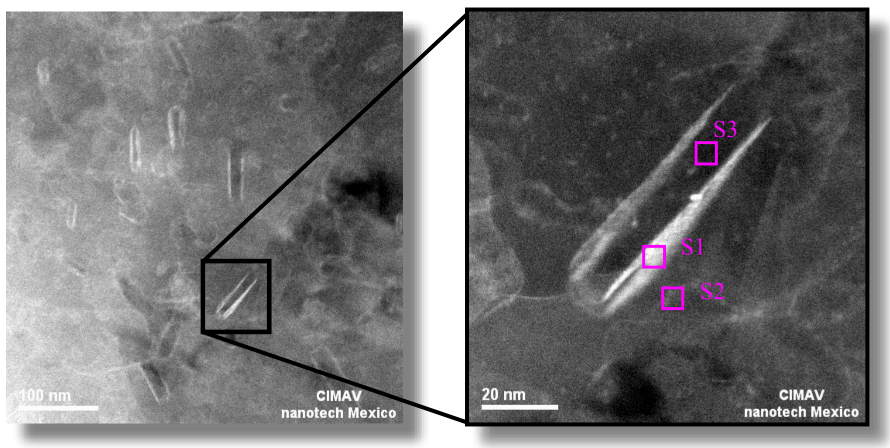
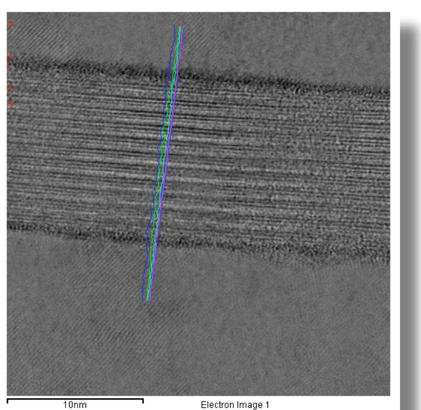
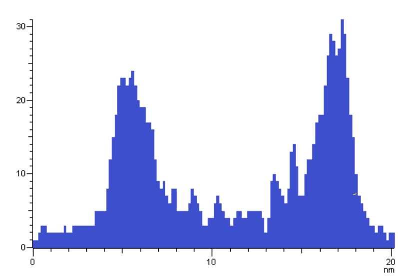




Spectrum	C	O	Al	Ag
S1	1.2	1.0	85.2	10.1
S2		3.4	93.6	
S3	2.0	3.3	90.4	1.4



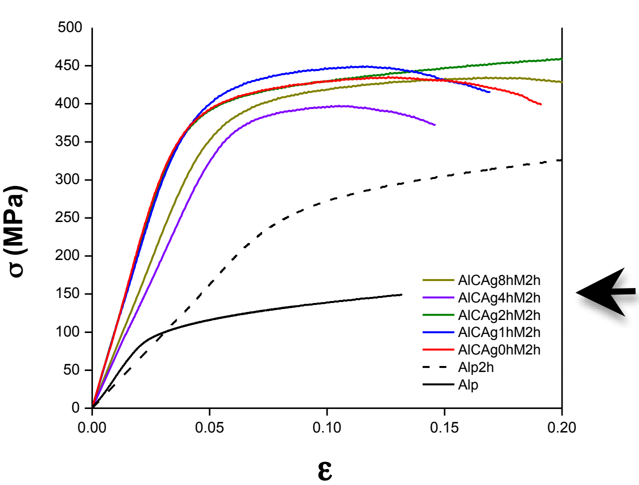


Figure 1. TEM micrographs of Al4C3 coated with silver in Al matrix and EDS analysis (elemental and line scan).

Figure 2. Stress-strain curves from the prepared composites (compressive tests). The samples display a notable increment on the yield strength due to the presence of hard particles in the Al matrix.

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