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Aluminum Mechanical Enhancing with Gr-Cu Nanoparticles Addition via High-Energy Ball Milling

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Aluminum (Al) composites, due to their low density and high strength have been applied in aerospace, ground transportation and military industry [1]. These materials can be obtained by mechanical milling achieving a homogenous dispersion of reinforcing particles in the metallic matrix [2]. Recent studies have obtained an increment on the mechanical properties with the addition of different reinforcing materials as nanotubes [3], graphenes [4] and carbon [5]. Additionally, mechanical properties were increased using cooper (Cu) as reinforcement in Al composites [6]. On the other hand, graphite (Gr) is employed as a reinforcing material because it is cheap, abundant and its particle size can be easily reduced.
The present work deals with some Al-based composites reinforced with Cu particles covered with Gr by mechanical milling. First: Cu particles were cover with Gr by mechanical milling, this process was carried out using a SPEX-8000M mill using steel balls with a ratio (milling media to powder) of 5:1 (in wt.), a mixture of Gr-10%Cu was milled during 2h. Next: mixtures of Al-1%GrCu (in wt.) were milled during 0, 1, 2, 4, and 8h periods. The milled composites were compacted under 900 MPa and sintered for 4h at 623K to achieve consolidated samples for the mechanical tests.

The figure 1 shows a micrograph of cross section of a Gr-Cu particle by SEM. It is noticed that the Cu (brightest area) is coated by graphite (darkest and uniform area). Additionally, it is evident a great rate of graphite exfoliation as a result of the mechanical milling processing. The micrographs in figure 2 present cross sections of composites milled at different milling times. With 0h we find that the reinforcing particles (Gr-Cu) are not integrated in the aluminum matrix, because this material is un-milled state. After milling, Gr-Cu particles are homogeneously distributed inside of the Al matrix, showing a significant reduction of particle size. Is important to mention, that due to the Gr "shell" the dissolution of Cu into Al is avoided.

Stress-strain curves of some Al-GrCu composites compared with milled and un-milled pure Al sample are presented in figure 3. Pure Al milled sample (Al_p-2h) presents an increment on its mechanical response compared with un-milled sample (Al_p-0h), this is caused by the increment of dislocation density and grain size reduction achieved by milling (cold working). On the other hand, with Gr-Cu addition, the studied composites showed a higher mechanical performance in comparison with pure aluminum sample. The maximum value of yield strength is reached with the Al-GrCu composite milled 2h. [9]

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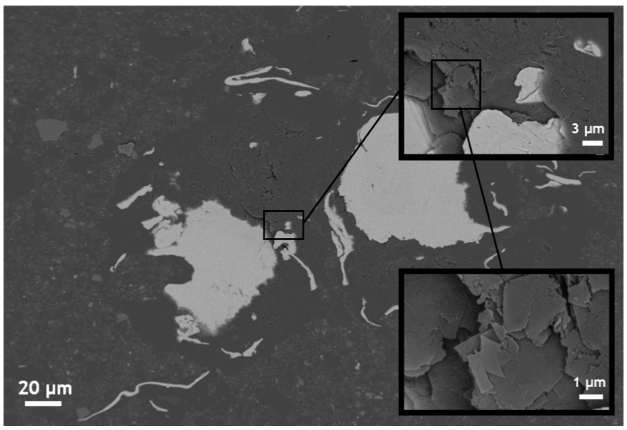


Figure 1. SEM micrograph of Gr-10%Cu sample milled 2h.

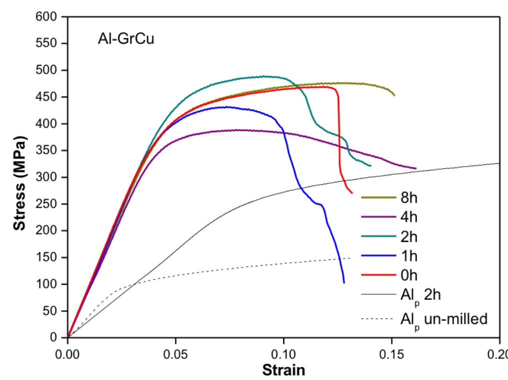
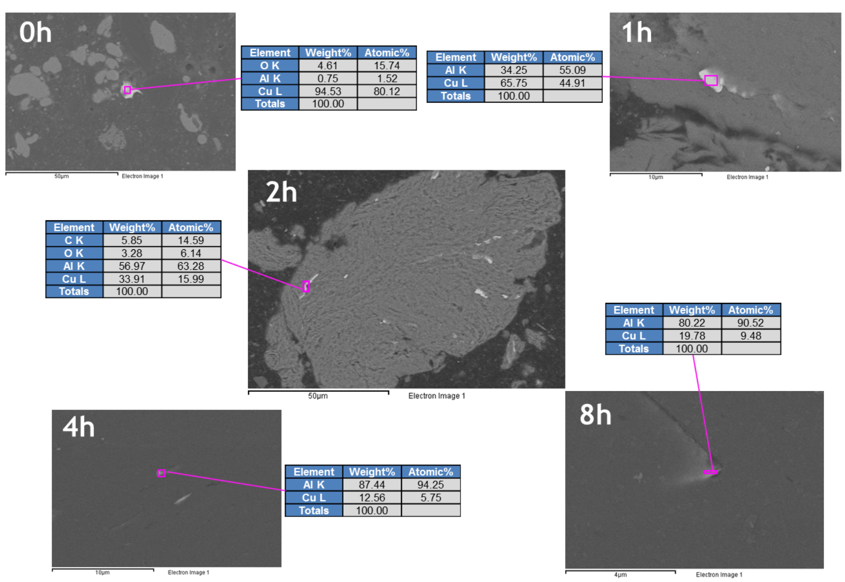


Figure 3. - Stress-strain curves.

Figure 2. SEM-EDS analyses in cross-sections of milled composites.



Element	Weight%	Atomic%
O K	4.61	15.74
Al K	0.75	1.52
Cu L	94.53	80.12
Totals	100.00	

Element	Weight%	Atomic%
Al K	34.25	55.09
Cu L	65.75	44.91
Totals	100.00	

Element	Weight%	Atomic%
C K	5.85	14.59
O K	3.28	6.14
Al K	56.97	63.28
Cu L	33.91	15.99
Totals	100.00	

Element	Weight%	Atomic%
Al K	80.22	90.52
Cu L	19.78	9.48
Totals	100.00	

Element	Weight%	Atomic%
Al K	87.44	94.25
Cu L	12.56	5.75
Totals	100.00	