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Effect of Dispersion of Particles Nanohybrid Reinforcing in the 6063 Aluminum Alloy

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Metal matrix composites (MMCs) are materials that present enhanced physical and mechanical properties compared to conventional metallic materials [1-2]. Among MMCs, the Al-based systems are promising engineering materials due to their low density and high specific strength [3]. Besides, there are significant research activities on reinforcements development of more than one component (Nanohybrid-NH) to improve the metallic matrix properties. Thus, this research aims to synthesize a novel 6063/CeO2/Gr composite to evaluate NH (CeO2/Gr) influence on mechanical properties. The CeO2/Gr NH synthesis was performed following the same route reported by the authors in reference [4]. This study used a 6063 alloy (A6063) as the metallic matrix. The MMCs were produced incorporating powder nanoparticles of CeO2/Gr (ratio 8:1) NH at a final concentration of 5 wt. %. The mechanical milling (MM) of the composites was performed at room temperature using a high-energy ball mill. The powder mass was 8.23 g, and the ball-to-powder ratio was kept at 5:1. Argon and methanol were used as the milling atmosphere and process control agent, respectively. The milling time was set to 5 h, based on previous results from Deaquino-Lara et al. [5] and Pérez-Bustamante et al. [6]. To carried out the mechanical characterization on solid samples, the milled powders were consolidated by uniaxial cold pressing at 1500 MPa for 60 s. Samples were compacted in cylindrical consolidation tooling of 6.7 mm of diameter and 12.3 mm of height and sintered under an argon atmosphere at 500 °C for 3h. Microstructural characterization was carried out through transmission electron microscopy (TEM) using a JEOL-JEM2200FS microscope. TEM specimens were prepared by focused ion beam (FIB) using a JEOL model JEM-9320 FIB. Mechanical characterization was conducted on the sintered composites using compression and microhardness Vickers (HV) testing, for which it was used an Instron machine model A3382 and a Leco LM300AT hardness tester, respectively. Fig. 1a shows an HRTEM image of CeO2/Gr NH used as reinforcing. Fig. 1b is a magnified view of CeO2/Gr NH into Fig. 1a (black square), which shows an interplanar distance of 0.337 nm corresponding to (2 0 0) planes of Gr. Besides, from Fig. 1a, it is observed that such planes are parallel to (1 1 1) planes of CeO2, (200)Gr // (111)CeO2. The SAED pattern corresponding is shown in Fig. 1c, and finally, Fig. 1d presents STEM/EDS elemental mapping corresponding to the CeO2/Gr NH, which confirms the homogeneous distribution of Gr, and CeO2. Fig.2 shows the results of Yield stress (YS), Strain (e), and Vickers microhardness (HV) obtained from the compression and microhardness testing for sintered composite. Curves of YS (■) and HV (▲) follow a similar behavior. The sample with lower YS and HV were sample A6063-non/milled. Comparing samples A6063- non/milled with A6063- milled observed the milling process's effect (reinforcement mechanisms of strain hardening and grain refinement) on YS and HV.

However, the strengthening result is more critically observed in sample A6063- CeO2/Gr NH (reinforcement mechanisms of second phase dispersion and thermal mismatch). The Strain (●) shows an inverse response to YS and HV. The powder metallurgy processing of composites based in a 6063 alloy and CeO2/Gr nanohybrid produced a notable crystal refining and favored the reinforcing particles' homogeneous dispersion. The samples reinforced with nanohybrid present an additional increase in mechanical properties due to graphite transformation into Al4C3. The primary strengthening mechanisms associated with the processing route are grain-size refining, the formation of the Al4C3 (strengthening by second phase dispersion), and the thermal mismatch.

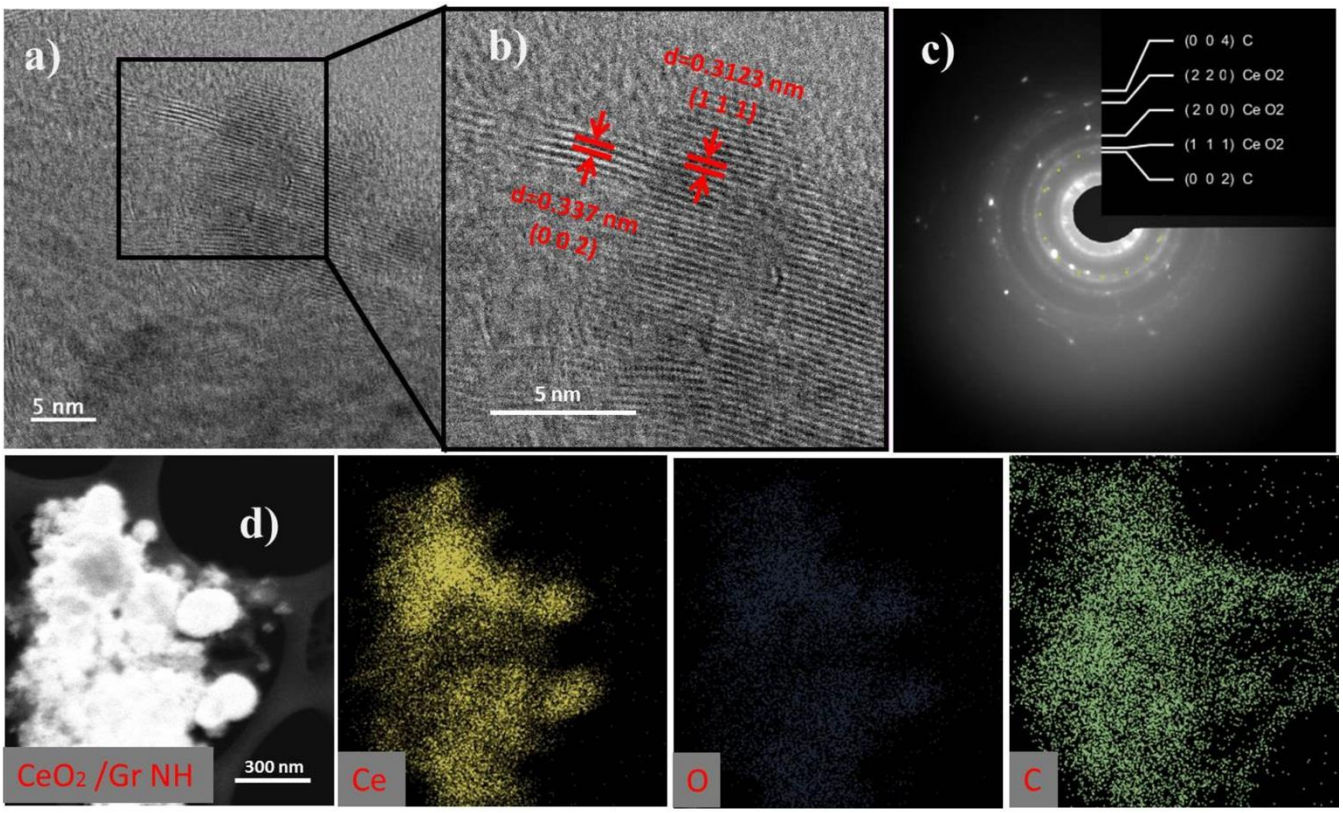

Figure 1. HRTEM micrographics (a,b), SAED pattern (c), and STEM/EDS elemental mapping (d) of CeO2/Gr NH.

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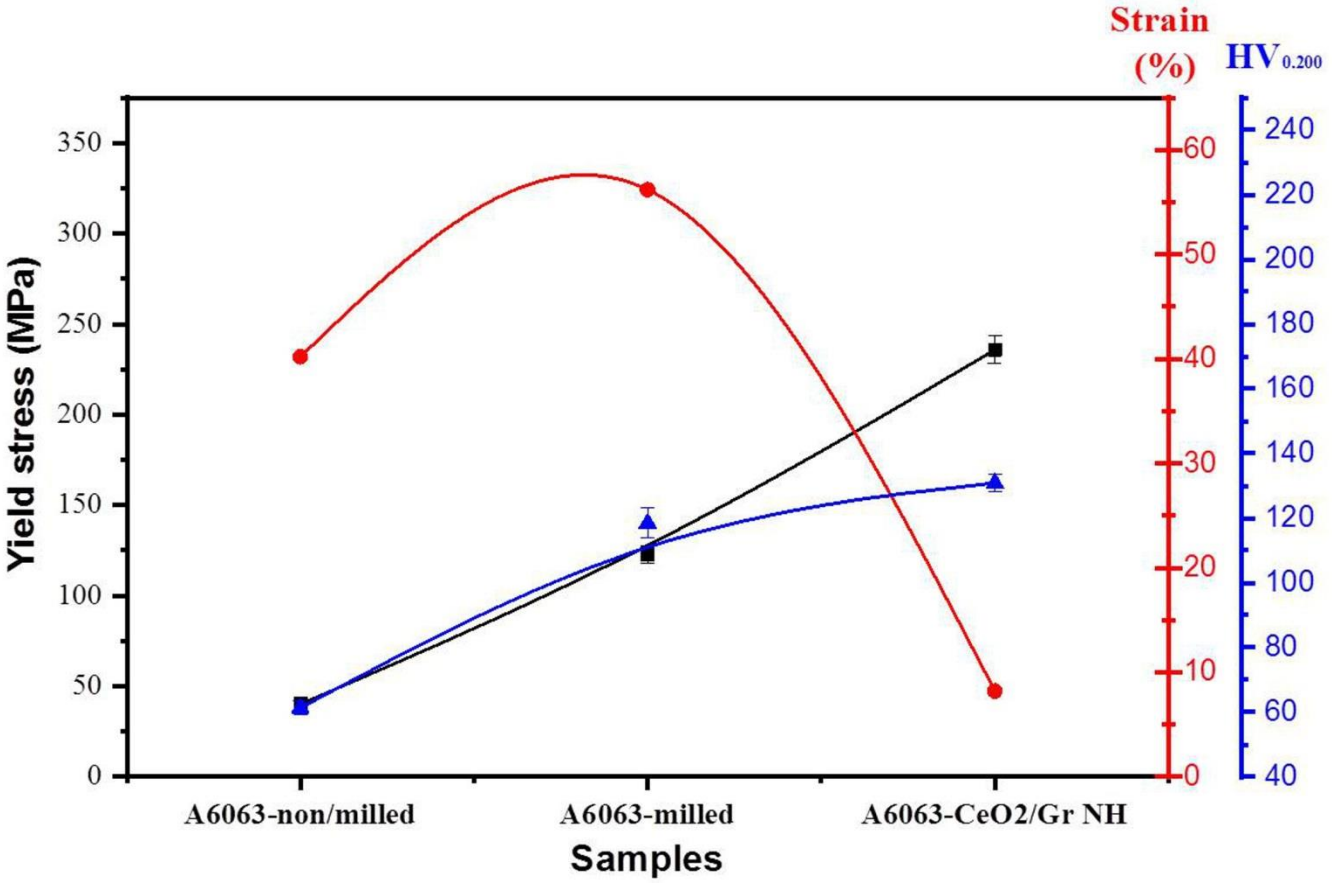

Figure 2. The plot of Yield stress (■), Vickers microhardness (▲), and Strain (●) values (b) of samples: A6063- non/milled, A6063- milled, and A6063- CeO2/Gr NH.

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