

Microstructural Analysis of Al-Al₄C₃ Nanocomposites Produced in Solid State

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A wide range of production techniques have been developed for aluminum matrix composites materials. This is generally done by dispersion of high temperature resistant fine ceramic reinforcement particles in the aluminum structure. Even though a number of processing techniques are available for producing Metal Matrix Composites (MMCs), the Mechanical Milling (MM) using Powder Metallurgy (PM), is a useful technique to synthesize composites of aluminum matrix. The conventional PM route for making Al matrix composites include: (1) Al is blended or mechanically alloyed with reinforcement particles; (2) compaction by die pressing, and (3) sintering [1]. The reinforcing particles Al₄C₃ have become an interesting reinforcing material because their high level of physical and mechanical properties, e.g. high temperature strength, thermal cyclic resistance, wear resistance and low linear expansion coefficient [2]. Therefore, the reinforcement of the aluminum using Al₄C₃ has recently become the subject of many studies and widely used for products and structures [3].

Al₄C₃ was synthesized by mixing 0.75 wt. % of Al powder and 0.25 wt. % of C powder, the mixture was mechanically milled in a high energy Simoloyer mill during 8 h. Argon was used as atmosphere milling. The device and milling media used were made from hardened steel. Consolidated samples were heat treated for 2h at 650°C. According with the X ray analyses, the product obtained is a mixture of Al-C-Al₄C₃ where the Al and C are remaining elements indicating that not all the mixture Al-C powder was transformed into to Al₄C₃. The Al-C-Al₄C₃ mixture was called M.

Al-based composites were produced by mixing Al powder (99.5 % purity) and various powder mixtures composed by Al-1, 2 and 3 wt. % of M. Each Al-M mixtures powders were mechanically milled in a high energy Simoloyer mill during 8 h. Argon was used as the milling atmosphere. Consolidated samples were sintered at different times: 2h, 4h and 6h at 550°C.

The Fig. 1 shows the X-ray diffraction patterns of Al-3 wt. % M in the as-milled condition and sintered at 2, 4 and 6 h. These results suggest the remaining C from the M powder reacts with the aluminum during the sintering process and the quantity of Al₄C₃ increase over the minimum detection limit of the X-ray technique used. The AFM topography analysis carried out on Al-2wt. % M at 6h of sintering sample (see Fig. 2) show a nanostructured state even after 6 hour of heat treatment. The profile graph shows the heights of the crystallites. Also the SEM secondary electron image of Fig.3 for the Al-1 wt. % M sample at 2h of sintering shows the existence of small crystallites in sintered zones after 4h of sintering.

The TEM bright-field image (see Figure 4) shows an Al₄C₃ nanoparticle into the Al matrix and the presence of small crystallites in the Al-2wt. % M sample after 2h of sintering. Some Al₄C₃

nanoparticle grows up on the crystallite as is appreciable in the TEM image. At seem the presence of the Al_4C_3 nanoparticle into the Al matrix avoid the crystallite grow during the sintering process,

References

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 [2] G. Abouelmagd. *Journal of Materials Processing Technology* (2004).
 [3] A. Santos et al. *Journal of Alloys and Compounds* (2010).

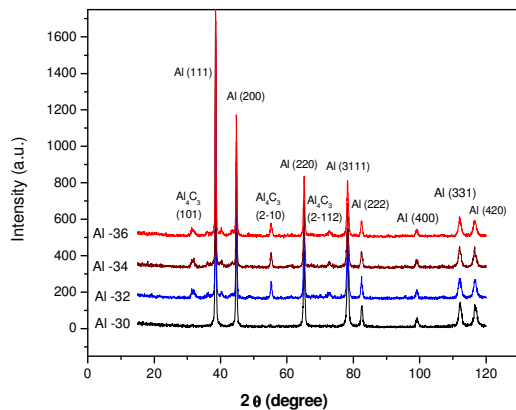


Figure 1. X-ray diffraction patterns of the Al-3 wt. % M at 2, 4 and 6 h of sintering samples.

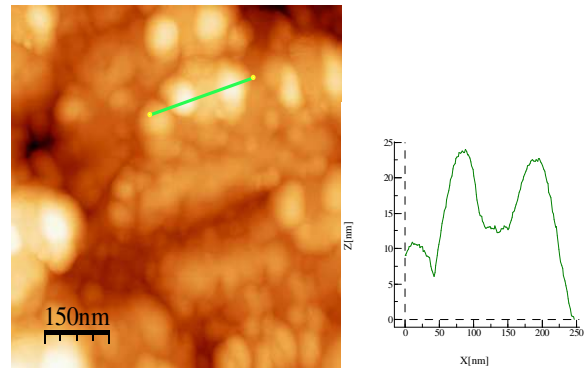


Figure 2. Atomic Force Microscopy topography image and profile graph of the Al-2 wt. % M at 6 h of sintering sample.

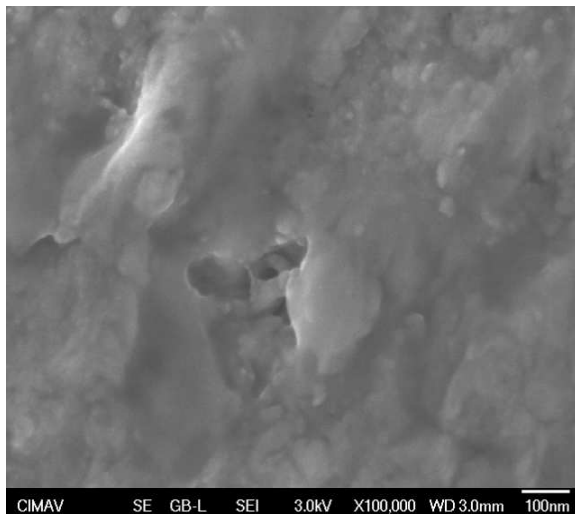


Figure 3. SEM secondary electron image for the Al-1 wt. % M sample at 2 h of sintering.

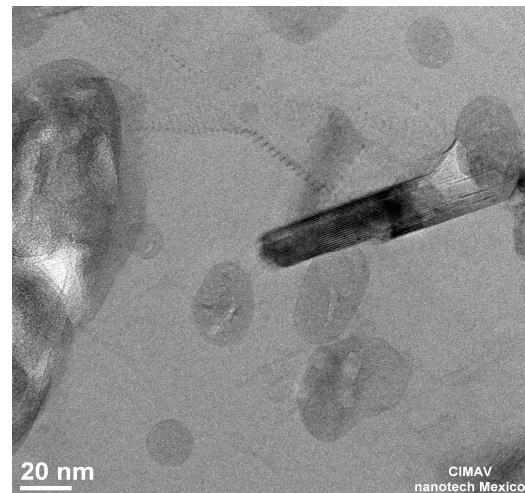


Figure 4. TEM bright-field that shows an aluminum carbide nanoparticle and some crystallites present in the Al matrix of the Al-2 wt. % M sample at 2 h of sintering.