Processing Routes for Al based Nano-Composites
High Performance Nano Composite Materials – Superior Weapons through Castings Program (Funded by the US Army – Benet Laboratories)

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Introduction

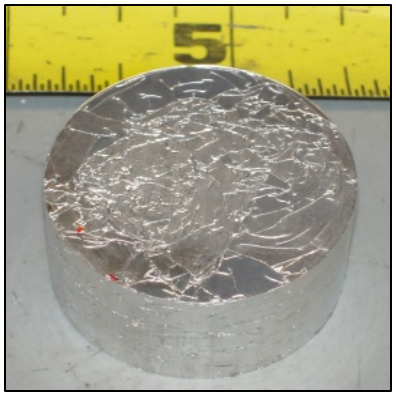
This project assesses the feasibility of manufacturing aluminum-titanium carbide (Al-TiC_p) nanocomposite materials by introducing nano-sized titanium carbide particles into a specially formulated molten aluminum alloy.

The main issues encountered when attempting to incorporate nano-sized TiC_p into molten aluminum result from the poor wettability of TiC_p by aluminum and the high surface tension of aluminum. We have found that $KAlF_4$ can mitigate these difficulties while reducing the tendency of the nano particles to cluster. We have also found that the presence of Mg in the alloy enhances incorporation of the nano particles into the molten alloy by decreasing the alloy's viscosity and surface tension.

Another difficulty arises from the high tendency of nano-sized TiC_p to oxidize when they are exposed to air at an elevated temperature. We have found that introducing the particles underneath the melt's surface mitigates their tendency to oxidize and facilitates their incorporation into the alloy.

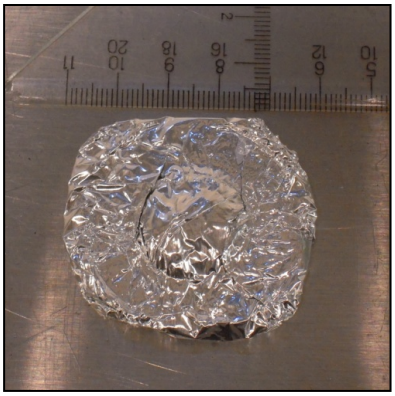
Methodology

Fifty grams of alloy were cut, cleaned, and placed in an alumina crucible. The alloy was melted in air in an electric resistance furnace at 900^{o}C. TiC particles (enough to constitute 4% by weight of the composite material) were then mixed with $KAlF_4$ flux in different flux:TiC ratios; namely, 5:1, 2:1, 1:1, and 0.5:1. This mixture was dried at 170^{o}C and stirred manually for 15 minutes. The mixture of flux and nano particles was then added to the melt using either one of three methods:



(1) sprinkling the mixture onto the surface of the molten alloy, or

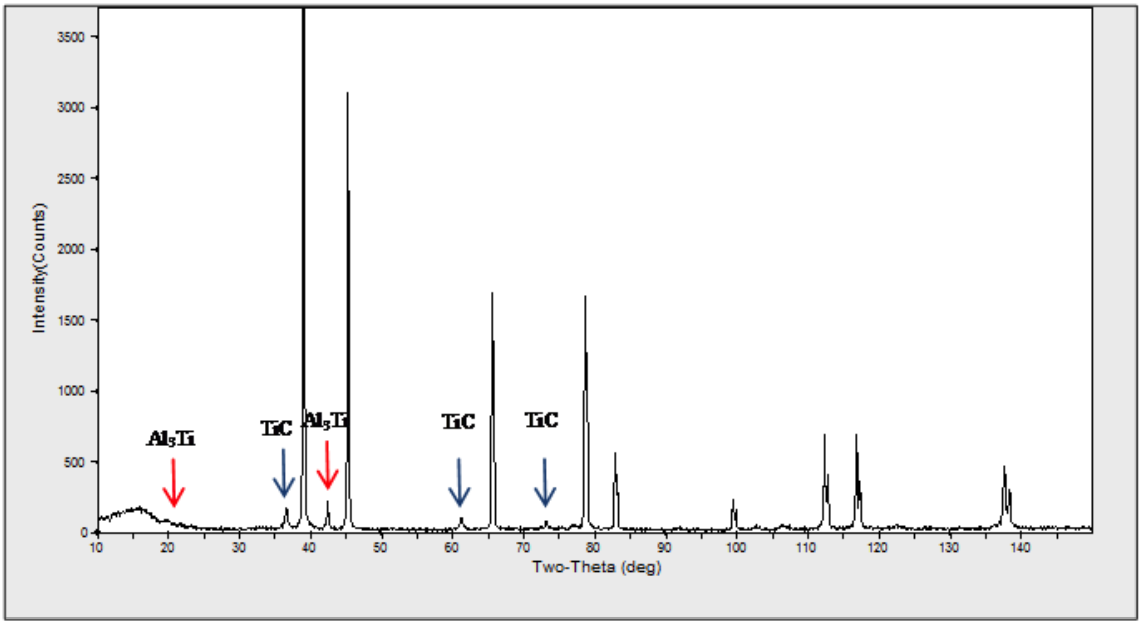
(2) plunging the mixture, which was previously encapsulated in aluminum foil, into the melt, or



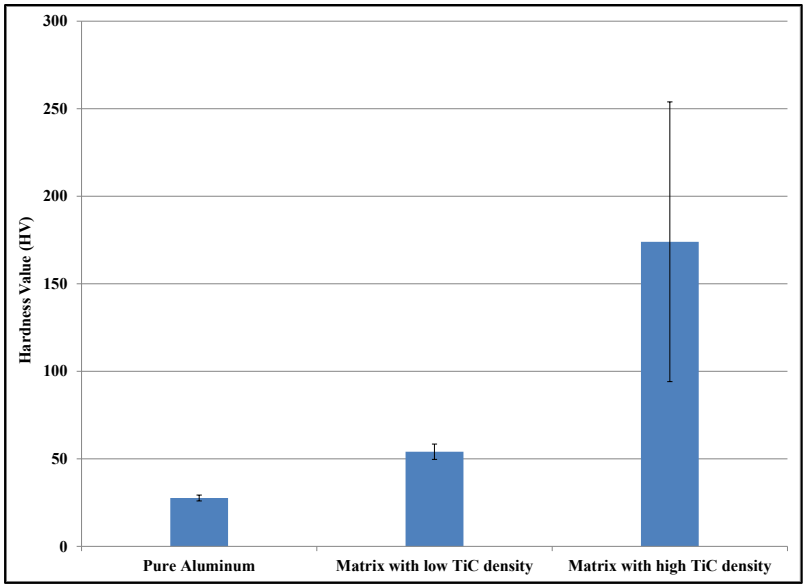
(3) plunging into the melt a tablet that is made from a $KAlF_4$-TiC mixture (5:1 ratio) pressed at 30 MPa and encapsulated in aluminum foil

After incorporation of the TiC particles into the bulk of the molten alloy, the surface of the melt was skimmed and the melt was stirred manually. In the third method, the aluminum foil was removed from the $KAlF_4$-TiC tablet before it was immersed in the melt. The charge was poured in a copper mold to solidify and then it was quenched into room temperature water.

Salient Results



X-ray diffraction pattern of Al-TiC composite prepared by the pressed tablet technique.



Measured hardness of Al-TiC composite prepared by the pressed tablet method.