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Metal/ceramic Interface Structures and Segregation Behavior in Aluminum-based Composites.

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Trimodal Al alloy (AA) matrix composites consisting of ultrafine-grained (UFG) and coarse-grained (CG) Al phases and micron-sized B_4C ceramic reinforcement particles exhibit combinations of strength and ductility that render them useful for potential applications in the aerospace, defense and automotive industries. A critical requirement for the application of trimodal composites is the creation of a strong interfacial bond between ceramic reinforcement and metal matrix to allow for effective load transfer. Different interfacial structures, including presence of amorphous layers between B_4C and the UFG Al phase [1–3], formation of nanocrystalline grains with diameters of 30-50 nm at the Al/B_4C interface [1,2] and segregation of Mg to Al/B_4C interfaces [3,4], have been reported in separate literatures. However information on the relationship between different interface morphologies (e.g., amorphous layers, nanocrystalline grains, etc.) and their chemical composition profiles remains absent in the literature.

The composite powder was fabricated via mixing cryomilling [5] and unmilled powder together and consists of 10 wt.% B_4C, 30 wt.% CG 5083 AA, and the balance of UFG 5083 AA. The consolidation of mixed powder was achieved via hot isostatic pressing. Electron-transparent TEM samples were prepared by focused ion beam (FIB) sectioning. TEM imaging was performed with either a JEOL 2500 or a FEI F20 UT Tecnai. Electron Energy Loss Spectroscopy (EELS) was done with either a JEOL 2100 or a F20 UT Tecnai. Elemental distribution maps were acquired using an FEI Super-X windowless EDXS detector (FEI Company, Hillsboro, OR) installed on the Titan G2 80-200 instrument. All microscopes are operated at 200 kV.

Figure 1a is a bright field TEM image demonstrating a layered structure between a B_4C particle and the CG Al phase. Figure 1b is a HRTEM image of the same interface that reveals a double-layered interface consisting of an amorphous layer and a Mg-rich layer. Figure 2 shows integrated EELS intensity line profiles across the Al/B_4C interfaces as a function of relative distance. Chemical composition profiling suggests the existence of Al oxide in conjunction with B_4C, while single or multiple layers of Mg-rich oxide are observed in between Al oxide and the alloy matrix. HRTEM and EELS experiments revealed an ultra-thin amorphous aluminum oxide layer separating a poly-crystalline MgO layer from the B_4C dispersoids. Precession assisted electron diffraction mapping was performed for the UFG Al/B_4C interface and revealed no preferred orientation of the grains in the UFG region with respect to the B_4C particle. Hence, grain orientation or texturing did not associate with the segregation of Mg at these interfaces.

References:

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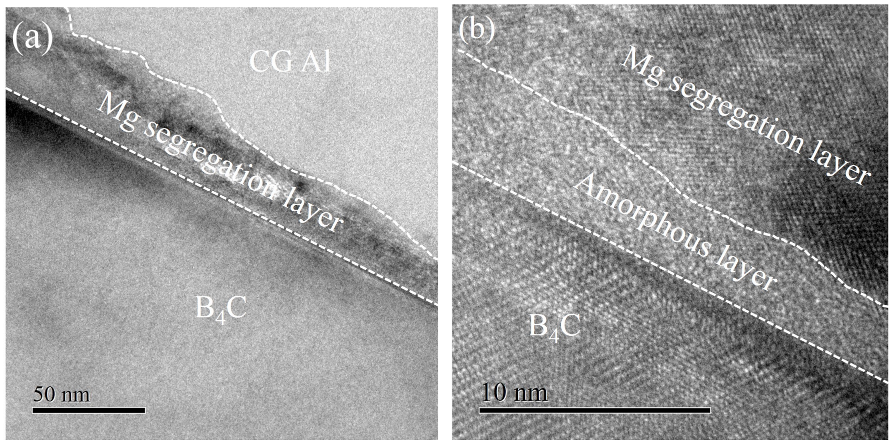

Figure 1. (a) Bright field TEM image of the interface between the B4C particle and the Al matrix showing the existence of Mg segregation layer; (b) HRTEM image showing a double-layered interface consists of amorphous layer and Mg-rich layer.

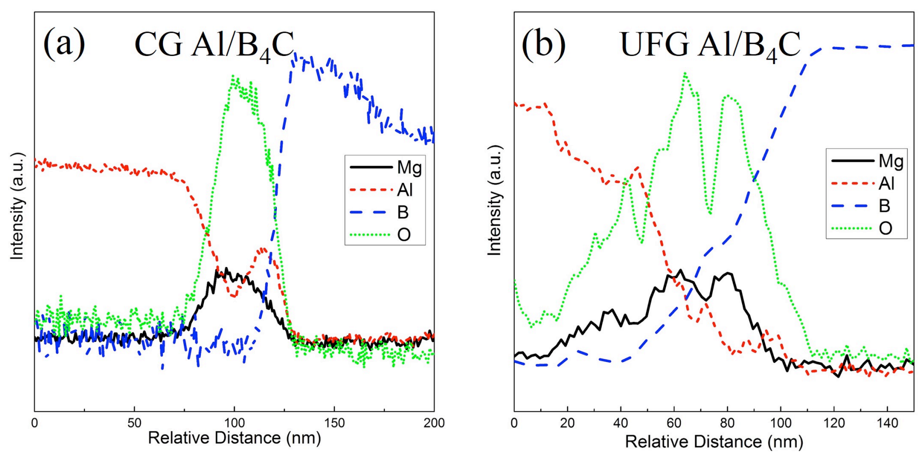

Figure 2. Integrated EELS intensity line profiles across (a) the CG Al/B_4C interface and (b) the UFG Al/B_4C interface.