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Preparation of Al_2O_3–TiC nanocomposite by mechano-chemical reduction of TiO_2 with aluminum and graphite

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ABSTRACT

Al_2O_3–TiC (AT) nanocomposite was synthesized by mechanical alloying (MA) of TiO_2, Al and graphite powder mixture. Effect of the milling time, starting composition and heat treatment temperatures were investigated. X-ray diffraction (XRD) was used to characterize the milled and annealed powders. The morphological and microstructural evolutions were studied by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Results show that the formation of TiC initiates after 20 h and completes after 35 h of milling. Residual Al in the 35 h milled powder was removed by lessening its content in the initial mixture to 20 wt.%. Annealing of the 80 h milled sample at 800 °C led to the obtaining maximum micro-hardness of 16.25 GPa. Mean crystallite size of 12 nm was estimated for 35 h milled sample with 28 wt.% Al. TEM and SEM images confirmed the nanocrystalline structure with very good distribution and homogeneity of TiC and Al_2O_3, respectively.

1. Introduction

Ceramic–matrix composites have attracted the attention of researchers for many years because of their potential for structural applications. Al_2O_3 reinforced with nano-sized particles such as TiC, WC, SiC, NbC, etc. represent a new class of materials with improved mechanical properties, hardness and wear resistance when compared to monolithic ceramics [1–7]. AT composites are widely used as substrate of magnetic heads and cutting tools due to their attractive mechanical properties and good electrical conductivity [8]. At present commercially available micro-sized AT composites are prepared by pressure-less sintering or hot pressing the direct mixtures of Al_2O_3 and TiC powders [9,10] during which severe grain coarsening and generation of metal oxides at the interface always take place due to relatively long holding time at high temperature [11]. Because of weak binding forces at the interface, grains are often pulled out when the AT composites are machined. This is especially detrimental if the crystallite size is large, which results in low product yield. Furthermore, the problem becomes more serious with the ongoing miniaturization of magnetic disk drive sliders. Thus it is a current trend to prepare fine-grained AT composites for future development of hard disk drive.

Mechanical alloying (MA) [12] has been considered as a powerful and practical process for fabrication of several advanced materials with unique properties [13], in particular, for those materials that are difficult to be obtained by the traditional way of liquid metallurgy. High thermal stable metallic glasses and amorphous alloys [14], nanocrystalline and nanocomposite materials [15,16], and refractory hard materials, including metal nitrides and silicides [17,18], carbides [19], hydrides [20] are examples of the advanced engineering materials that are prepared at room temperature, using the MA method.

There have been some attempts to produce AT composite by mechanical alloying. Jiang and coworkers investigated the in situ synthesis of Al_2O_3–TiC nanocomposite from a mixture of Ti, graphite and Al_2O_3 (nano) powders by ball milling [21]. Razavi et al. used elemental powders of Ti, Al and graphite. TiC–Al_2O_3 was formed during the annealing of milled powder at oxygen atmosphere with some impurities [22].

The present study proposes an attractive route for preparation of AT nanocomposite powders at room temperature, by ball milling a mixture of TiO_2, Al and graphite powders. For the first time, these inexpensive raw materials (TiO_2, Al and graphite) were used for preparation of AT composite. One aim of this work thus is to offer an inexpensive technique for fabrication of technologically important materials.

2. Experimental details

Mechanical alloying was performed in a planetary ball mill at nominal room temperature with a vial rotation speed (cup speed) of 500 rpm. Pure Al (Fluka Co., 99.9 wt.%, <200 μm), graphite (MERCK, 99.9 wt.%, <50 μm) and TiO_2 (MERCK, 99.9 wt.%, <50 μm) powders were mixed to give the desired AT composite on the basis of following reaction:

$$TiO_2 + \frac{4}{3}Al + C = \frac{2}{3}Al_2O_3 \;\; (53\,wt.\%) + TiC \;\; (47\,wt.\%) \tag{1}$$

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