Advanced Powder Technology 23 (2012) 334–337

Contents lists available at ScienceDirect

Advanced Powder Technology

journal homepage: www.elsevier.com/locate/apt

Original Research Paper

Mechanochemical synthesis of Al_2O_3/Co nanocomposite by aluminothermic reaction

S.N. Hosseini, F. Karimzadeh *, M.H. Enayati

Department of Materials Engineering, Isfahan University of Technology, Isfahan 84156-83111, Iran

ARTICLE INFO

Article history:
Received 23 December 2010
Received in revised form 7 April 2011
Accepted 12 April 2011
Available online 27 April 2011

Keywords:
Nanomaterials
Nanocomposites
Ceramic matrix composites
Mechanochemical reaction

ABSTRACT

In this work, Al_2O_3/Co nanocomposite was successfully prepared by mechanochemical reaction between Co_3O_4 and Al powders in a planetary high energy ball mill. The mechanism of the reaction was dealt using X-ray diffraction (XRD), differential thermal analysis (DTA), and thermodynamics calculations. It was found that Co_3O_4 reacts with Al through a self-sustaining combustion reaction after an incubation period of 50 min and the reaction between Co_3O_4 and Al involves two steps. First, Co_3O_4 reacts with Al to form CoO and Al_2O_3 at the temperature around melting point of Al, and at higher temperature, CoO reacts with remaining Al to form Co and Al_2O_3. Mechanical activation process decreases the reaction temperature from 1041 °C for as-received Co_3O_4 and Al powder mixture to 869 °C for 45 min milled powders. After annealing of powder milled for 12 h, no phase transformation has been detected. The crystallite sizes of both α-Al_2O_3 and Co remained in nanometeric scale after annealing at 1000 °C for 1 h.

1. Introduction

The alumina ceramic is one of the most widely used structural materials in modern technology for several reasons including good wear resistance and chemical stability. However, the application of alumina is limited by its high brittleness. Reinforcing of brittle ceramics by the addition of metallic or intermetallic phases is considered in modern technological processes as the possibility to obtain new materials with improved mechanical properties [1–4]. Basically, introducing the reinforcement phase can be performed by two routes. One route is ex-situ addition of reinforcement particles by techniques such as hot-pressing [5–8]. The second route is in situ formation of reinforcement phase via a displacement reaction. The later route can be done by various deposition techniques and chemical methods but mechanochemical process has some advantages over other fabrication methods such as capability of producing large quantity of materials for a low cost and nano-sized structures with high uniformity [5,9].

It is well known that when a highly exothermic chemical system is mechanically treated by ball milling, a combustion-like reaction can take place. This process is generally referred as mechanically induced self-propagating reaction (MSR). This process has the advantages of both self-propagating high-temperature synthesis (SHS) and mechanical alloying (MA) techniques [10].

Many works have been focused on synthesis of different nanocomposites e.g. Al_2O_3/Mo [4], Fe_3Al/Al_2O_3 [5], Zn/Al_2O_3 [11], $NiTi/Al_2O_3$ [12], and $NiAl/Al_2O_3$ [13] by mechanochemical reduction of metals oxides by Al while a few works have been done on mechanochemical reaction of Al and cobalt oxides. Li and co-workers used mechanochemical reaction between CoO and Al to prepare Co matrix with Al_2O_3 particles [9]. But synthesis of a nanocomposite with Al_2O_3 matrix and Co reinforcements via mechanochemical reaction has not been reported.

In this study, Al_2O_3/Co nanocomposite has been fabricated via redox reaction of Co_3O_4 and Al powders during milling. Also thermodynamics calculation, thermal analysis and structural evolutions were carried out to investigate the reaction mechanism.

2. Experimental procedure

The appropriate proportion of Co_3O_4 and Al powder mixture (Co_3O_4-23 wt.% Al) according to the reaction of Al and Co_3O_4 was milled in a planetary high energy ball mill using hardened chromium steel vial and balls. Ball milling was performed at room temperature under an argon atmosphere. The rotation speed of the vial and the ball to powder weight ratio were 600 rpm and 15:1, respectively. No process control agent (PCA) was used. The temperature increment of external surface of vial was recorded by a pyrometer. DTA measurements (BAHR model STA 503) were carried out to investigate the effect of milling on the Co_3O_4–Al displacement reaction. DTA experiments were conducted using Al_2O_3 crucibles, under dynamic Ar atmosphere, in the temperature range of 25–1200 °C

* Corresponding author. Tel.: +98 311 3915744; fax: +98 311 3912752.
E-mail address: karimzadeh_f@cc.iut.ac.ir (F. Karimzadeh).

0921-8831/$ - see front matter
doi:10.1016/j.apt.2011.04.008