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Technical Report

In situ processing and aging behaviour of an aluminium/Al_2O_3 composite

G.H. Zahid [a,*], T. Azhar [a], M. Musaddiq [a], S.S. Rizvi [a], M. Ashraf [a], N. Hussain [a], M. Iqbal [b]

[a] Materials Division, Pakistan Institute of Nuclear Science and Technology, P.O. Nilore, Islamabad, Pakistan
[b] Physics Division, Pakistan Institute of Nuclear Science and Technology, P.O. Nilore, Islamabad, Pakistan

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ABSTRACT

Reactive sintering involving a displacement reaction between aluminium and CuO powders was applied to fabricate an aluminium based composite. The two powders were mixed in a ball mill and uniaxially pressed before sintering in nitrogen atmosphere at 900 °C. During sintering a displacement reaction between CuO and aluminium occurred, which resulted in in situ synthesis of alumina particles. Differential thermal analysis (DTA), X-ray diffractometry (XRD), optical and scanning electron microscopies were used to investigate the phase and microstructural changes taking place during processing of the composite. Results revealed that no chemical reaction occurred during ball milling and Al_2O_3 phase developed in two stages during sintering of the compact. Below 700 °C, amorphous alumina formed which transformed to crystalline alumina at higher temperature. Aging response of the composite was examined as a function of time in temperature range of 180–220 °C. Composite attained a peak hardness value of 133 H_v after 4 h of aging at 200 °C.

1. Introduction

Metal matrix composites (MMCs) form an important class of structural materials. The combination of properties such as high specific strength and stiffness, good wear resistance and elevated temperature stability makes these materials suitable for many structural applications in a range of technologies [1,2]. However, difficult and expensive processing procedures have prevented their extensive use [3]. Conventionally, metal matrix composites are produced by powder metallurgy or ingot metallurgy techniques. Both of these processing routes suffer from certain shortcomings. For example, in case of powder processing, high pressures at elevated temperatures are usually required to densify the composites. This gives rise to processing costs and composites become less competitive to conventional materials. On the other hand, the melting and casting route, though cost effective, experiences problems like poor wettability between ceramic reinforcements and the melt, inhomogeneous distribution of reinforcements and unwanted interfacial reactions [4]. Another problem with the conventionally produced composites is the thermodynamic instability, which restricts their application at elevated temperature for longer times.

In order to overcome the above difficulties, novel processing techniques based on in situ production of composites have emerged in the last couple of decades [5–14]. In the in situ synthesis, chemical reactions between elements or compounds are utilized to produce reinforcements in the metal matrix. The in situ-formed reinforcements offer the advantages of finer size, non-contaminated surface and matched interface, excellent dispersion in the matrix and high thermodynamic stability.

The commercial exploitation of these new technologies requires the understanding of the various processing steps leading to the control of the microstructure and properties of the materials. The aim of the present work was to synthesize an aluminium matrix composite using the reaction based technology and to examine the aging behaviour of the composite as a function of time and temperature.

2. Experimental procedures

Starting materials for the in situ synthesis of composite were aluminium and CuO powders. Particle size range of aluminium powder was −325 to +600 mesh and that of CuO was −600 mesh. Aluminium powder was degassed at a temperature of 450 °C until a pressure of 5×10^{-6} mbar was reached. The powders were mixed in aluminium to CuO weight ratio of 4:1. Mixing was performed in a planetary ball mill (RETSCH) at 150 RPM for 2 h. Tungsten carbide ball with a diameter of 10 mm were used to mill the powders. During milling nitrogen atmosphere was maintained and a ball to powder ratio of 5:1 was used. Powder mixture was then uniaxially pressed at 600 MPa and the compacts so obtained were sintered in nitrogen atmosphere. Before sintering, differential thermal analysis (DTA) of the mixture was carried out. This provided useful information about the sequence of reactions between Al and CuO. X-ray diffractometry (XRD), optical and scanning electron microscopies were used to investigate the phase and microstructural changes occurring during processing of the composite.

* Corresponding author. Tel.: +92 51 2208197; fax: +92 51 2207374.
E-mail address: gulzarzahid@hotmail.com (G.H. Zahid).

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