

Effect of interfacial reaction on age-hardening ability of B₄C/6061Al composites

Y.Z. Li^a, Q.Z. Wang^{b,*}, W.G. Wang^a, B.L. Xiao^a, Z.Y. Ma^{a,**}

^a Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, 72 Wenhua Road, Shenyang 110016, China

^b Key Laboratory of Nuclear Materials and Safety Assessment, Institute of Metal Research, Chinese Academy of Sciences, 72 Wenhua Road, Shenyang 110016, China

ARTICLE INFO

Article history:

Received 3 July 2014

Received in revised form

4 October 2014

Accepted 12 October 2014

Available online 18 October 2014

Keywords:

Composites

Aluminum alloys

Age hardening

Hardness

Interfaces

Mechanical properties

ABSTRACT

The age-hardening ability of B₄C/6061Al composites, fabricated by powder metallurgy technique, were systematically investigated through varying B₄C contents (0–30 wt%), hot-pressing temperatures (560–620 °C) and holding times (30–120 min). The results showed that the quantity of Mg₂Si precipitates formed in the composites after T6-treatment decreased with increasing B₄C content and hot-pressing temperature, attributable to the consumption of Mg resulting from interfacial reactions. The main interfacial reaction products were MgAl₂O₄ and Al₃BC. The formation of MgAl₂O₄ was determined to be the primary factor degrading the age-hardening ability of the composites. Reducing the hot-pressing temperature and holding time and increasing the Mg content were beneficial to improving the age-hardening ability of the composites. It was experimentally verified that 580 °C and 30 min were the optimal hot-pressing temperature and holding time, and the amount of additional Mg should be less than 1.5 wt%, when considering both the age-hardening ability and comprehensive properties of the composites.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Aluminum matrix composites (AMCs) have received significant attention as candidate materials for aerospace and automotive applications in recent years. Generally, AMCs have higher specific modulus, strength, wear resistance and elevated-temperature resistance than unreinforced alloys [1,2]. As a kind of new reinforcement, B₄C has the lowest density (about 2.52 g/cm³) among ultrahard materials, and its hardness (9.5+ in Mohs' scale) is just below that of the diamond and c-BN. Also, B₄C exhibits similar thermal expansion coefficient, thermal stability and chemical inertness to SiC. Thus, B₄C becomes an alternative to SiC and Al₂O₃ for fabricating advanced AMCs with high stiffness, good wear resistance and impact resistance [3,4]. In addition, the specific ability of the B-10 isotope to capture neutrons makes the B₄C/Al composite an ideal neutron absorbing material in nuclear industries [5,6].

Commercial Al alloys are usually used as the matrices of AMCs because of their low cost and availability. For the AMCs with heat treatable Al alloys as the matrices, the mechanical properties could be significantly modified through heat treatment [7,8]. Aging is a

common heat treatment method to improve the mechanical properties of AMCs. The age-hardening behavior of AMCs has been the subject of a number of investigations.

Appendino et al. [9] compared the aging behavior of 6061Al and 14 vol%SiC/6061Al composite. It was reported that the aging behavior of the composite was similar to that of the matrix, although accelerated aging kinetics was observed for the composite. The similarity of the aging behavior between the composites and the matrix alloys was also observed by Chu [10] and Dutta et al. [11]. A theoretical model was developed by Dutta et al. to predict the rate of precipitation. In summary, the age-hardening behavior of AMCs is mainly controlled by the characteristics of the matrix alloys and the optimum aging parameters have already been obtained for some common AMCs in previous studies [9–13].

In addition to the characteristics of the matrixes, the interface reactions would also affect the aging behavior of the composites. Especially, those reactions involving the alloy elements would change the composition of the matrixes and consequently change the age-hardening ability of the composites [14–18]. For some composite systems, these reactions could enhance the age-hardening ability of the composites. For example, in an Al–Mg–SiC system, the reactions between Al and SiC increased the Si content in the matrix alloy, leading to a modified age-hardening ability of the composite, though the increment was not significant [14]. For some other composite systems, these reactions would deteriorate the age-hardening ability of the composites. For example, in an

* Corresponding author. Tel./fax: +86 24 23971749.

** Corresponding author. Tel./fax: +86 24 83978908.

E-mail addresses: qzwang@imr.ac.cn (Q.Z. Wang), zya@imr.ac.cn (Z.Y. Ma).

Al–Mg–Si–Al₂O₃ system, the reaction between Mg and Al₂O₃ resulted in the consumption of Mg, degrading the age-hardening ability of the composite [15].

As for the Al–B₄C system, very few studies reported on the interfacial reactions involving alloy elements and their effects on the aging behavior of the composites. Some investigations mentioned that Mg involved reactions possibly produced negative impact on the age-hardening ability of B₄C/Al composites, but did not provide experimental evidences and detailed analyses [18].

For 6061Al-based composites, the age-hardening ability may be easily affected by the addition of reinforcements because of low content of the alloy elements Mg and Si. Although the aging behavior of 6061Al-based composites was reported in some studies [19,20], most of these studies focused on the aging kinetics and did not account for the effects of the reinforcement on the age-hardening ability of these composites. To the best of our knowledge, investigation of aging behavior of B₄C/6061Al composites is lacking up to this point.

In the present study, B₄C/6061Al composites were fabricated by powder metallurgy (PM) technique. The effect of B₄C on the age-hardening ability of B₄C/6061Al composites was systematically investigated through varying the B₄C contents (0–30 wt%), hot-pressing temperatures (560–620 °C) and holding times (30–120 min). The aim is to elucidate the effect of interfacial reaction on the age-hardening ability of B₄C/6061Al composites.

2. Experimental

B₄C/6061Al composites were fabricated by PM technique using 6061Al alloy with a nominal composition of Al–1.0 Mg–0.65Si–0.25Cu (wt%) as the matrix and B₄C as the reinforcement. The mean sizes of aluminum powders and B₄C particles were 13 and 7 μm, respectively. The as-received B₄C particles were dried at 150 °C for 8 h, and then mechanically mixed with the Al powders for 8 h in a bi-axis rotary mixer with a rotation speed of 50 rpm and a ball to powder ratio of 2:1. The as-mixed powders were cold pressed in a cylindrical die under a pressure of 50 MPa and then hot pressed under a pressure of 30 MPa, producing the composite billets 55 mm in diameter and 60 mm in height. For comparison, unreinforced 6061Al alloy was also fabricated under the same fabrication conditions.

In order to clarify the key factors influencing the interfacial reactions and age-hardening ability separately, three series experiments were designed in the present study, as following:

- (I) B₄C/6061Al composites reinforced with 0, 15, 20, 25 and 30 wt% B₄C particles were hot pressed at 620 °C with a holding time of 120 min to investigate the effect of B₄C content on the age-hardening ability (Section 3.2). 620 °C is between the solidus and liquidus of the matrix alloy and can ensure the occurrence of partial liquid phase during the fabrication of the composites.

- (II) 20 wt%B₄C/6061Al composites were fabricated at 560, 580, 600 and 620 °C to investigate the effect of the hot-pressing temperature on the age-hardening behavior. Furthermore, 20 wt%B₄C/6061Al composites hot-pressed at 620 °C with different holding times of 30, 60, 120 min were also fabricated to investigate the effect of holding time on the age-hardening behavior (Section 3.3).
- (III) 20 wt%B₄C/6061Al composites with different extra Mg additions (0, 0.5, 1, 1.5 wt%) were fabricated at a hot pressing temperature of 620 °C and a holding time of 120 min to investigate the influence of Mg content on the age-hardening ability (Section 3.4).

To reduce the defects and enhance the mechanical properties, all the hot-pressed billets were hot forged at 480 °C into disc plates 12 mm in thickness and then subjected to the microstructural examinations and property tests. The densities of the composites were measured using the Archimedes principle. The microstructures and phase compositions were examined and analyzed by scanning electron microscopy (SEM, quanta 600) and X-ray diffraction analyzer (D/max 2400). Semi-quantitative analysis was also performed to evaluate the variation of the relative abundances of the phases. For each characterized phase, the evaluation was realized by measuring the intensities of three characteristic diffraction lines free of overlap and by comparing the obtained values from one sample to another. Differential scanning calorimetry (DSC TA-Q1000) was conducted in the flowing argon atmosphere with a heating rate of 10 °C/min. Small pieces of specimens (50 mg) were cut from the powder compacts which were hot pressed at a lower temperature of 400 °C to ensure enough densification and restrain interfacial reactions and element diffusion.

Age hardening behavior of the composites and matrix alloy were characterized using the Brinell hardness measurement under both as-solutionized (solution treated at 530 °C for 2.5 h, water quenched) and peak-aged (T6, solution treated at 530 °C for 2.5 h, water quenched, and then aged at 175 °C for 6 h) conditions. Six specimens per condition were measured to ensure the accuracy of results. Dogbone-shaped tensile specimens (25 mm gage length, 4 mm gage width and 2 mm gage thickness) were electrical discharge machined from the forged disc plate. Tensile tests were conducted under T6 condition using an INSTRON 5582 tester at a strain rate of 10^{−3} s^{−1}. The property values for each condition were calculated by averaging three test results.

3. Results

3.1. B₄C particles

Fig. 1 shows the SEM micrograph and the XRD pattern of the B₄C particles. It is noted that the B₄C particles exhibited a polygonal morphology with blunt edges and small aspect ratios

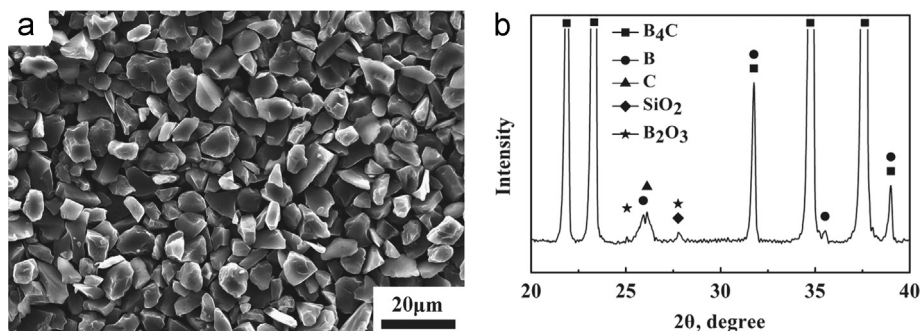


Fig. 1. (a) SEM micrograph and (b) XRD pattern of as-received B₄C particles.

Download English Version:

<https://daneshyari.com/en/article/1574616>

Download Persian Version:

<https://daneshyari.com/article/1574616>

[Daneshyari.com](https://daneshyari.com)