Materials Science & Engineering A 647 (2015) 62–65

Contents lists available at ScienceDirect

Materials Science & Engineering A

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

Short communication

Effect of the interfacial reaction of aluminum and yttrium oxide on aging behavior of aluminum–magnesium–silicon alloy reinforced with yttrium oxide modified sub-micron alumina

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ARTICLE INFO

Article history:
Received 29 July 2015
Received in revised form
27 August 2015
Accepted 28 August 2015
Available online 2 September 2015

Keywords:
Interfacial reaction
Age hardening
Aluminum alloys
Microstructural evolution
Surface modification
Rare-earth

ABSTRACT

Age-strengthening behavior of Al–Mg–Si alloy composites reinforced with sub-micron alumina particles modified by yttrium oxide under the temperature of 130 °C, 160 °C and 190 °C was investigated. The mechanical performances of unmodified and modified composites after the aging treatment were evaluated with the tensile test. The results indicate that the hardness level of modified composites is obviously increased compared to unmodified composites at different aging states, and the process of aging precipitation of the matrix alloy in modified composites is accelerated by the interfacial reaction of aluminum and yttrium oxide. The aging microstructures of modified composites have a significant difference compared to non-modified composites, and present a large amount of dislocations and precipitates in the matrix alloy. The modified composites treated by the aging exhibit excellent tensile properties. It is suggested that the interfacial reaction resulted from the surface modification of particles with the rare-earth yttrium oxide is beneficial in promoting the process of aging precipitates and strengthening the aging microstructures and properties of Al alloy matrix in modified composites.

1. Introduction

The aging behavior of discontinuously reinforced composites has been a subject of great interest both from scientific and technological view points. Extensive researches have indicated that the aging behavior of these composites depends mainly on the reinforcements, alloy composition, the nature of matrix-reinforcement interface and other processing parameters [1–3]. There are few reports, however, on discussing the effect of the interfacial reaction of discontinuous reinforcements in metal matrix on the aging behavior of its reinforcing composites. In our previous researches, we used the rare-earth oxide to modify the surfaces of sub-micron alumina particles and studied the effect of modified alumina particles on the properties of Al–Mg–Si alloy matrix composites, and indicating that the surface modification of sub-micron alumina particles with rare-earth can effectively improve the dispersibility of particles in the Al matrix. The mechanical properties of modified composites are improved significantly due to the interfacial reaction between the rare-earth oxide and aluminum matrix [4,5]. Literatures [6,7] also studied the effects of the addition of as-received sub-micron alumina particles on the aging behavior of reinforcing Al composites, and drew the conclusions of some unusual characteristics of rare dislocations and precipitates in the aging matrix. Based on the previous studies, in the present work, we intend to explore the effects of the interfacial reaction of Al matrix and yttrium oxide on the age hardening behavior at different aging temperature in modified composites filled with sub-micron alumina particles modified by yttrium oxide, and the tensile properties of aged-treatment composites are also evaluated.

2. Experimental procedures

Surface modification of sub-micron alumina particles (0.3 µm, nearly spherical) using Y_2O_3 was carried out by a liquid-phase coating method, and the Al–Mg–Si matrix composites reinforced by Y_2O_3 coating-α-Al_2O_3 particles with 30% volume fractions were fabricated by squeeze casting technology. These detailed experimental procedures are available in our previous publication [8]. The specimens were first solution-treated at 530 °C for 1 h and water-quenched at room temperature. After solution treatment, the modified composites were aged at 130, 160 and 190 °C for

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http://dx.doi.org/10.1016/j.msea.2015.08.089
0921-5093/

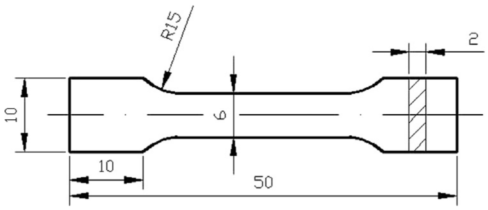

Fig. 1. Shape and dimension of tensile specimen (mm).

periods up to 100 h. For comparison, the unmodified composites were also treated as above mentioned.

The age hardening responses of composites were characterized by Brinell–Vickers hardness measurement (HBV-30A), with triplicate specimens and five measurements per condition to ensure the accuracy of results. The microstructures of aged composites were characterized by employing a Phillips T20 transmission electron microscope, operating at 120 kV. Tensile tests for specimens with artificial aging treatment were carried out on an Instron-1186 Universal Electron-Tension machine with a cross load speed of 0.5 mm/min. The size of tensile specimen is shown in Fig. 1. Three specimens were tested for each composites, and the testing temperature was at room temperature.

3. Results and discussion

Fig. 2 gives the age hardening curves of Al–Mg–Si alloy composites reinforced by sub-micron α-Al_2O_3 particles before and after surface modification using Y_2O_3 with 30% volume fractions at 130, 160 and 190 °C, respectively. As shown, it is clear that under three different temperatures, the hardness values of modified composites at different stages of aging are all higher than those of non-modified composites, and both non-modified and modified composites with 30 vol% particles show higher age hardness during the aging at 130 °C compared to the aging at 160 and 190 °C. From the trend of change on the hardening curves, the hardness values of non-modified composites have a little change, while the modified composites present obvious age hardening peaks, and their peak hardening values have an average increasement of approximately 8% relative to the non-modified composites. In addition, from the peak aging time, the non-modified composites appear at about 10, 8 and 7 h, while the modified composites decrease to about 9, 7 and 6 h at 130, 160 and 190 °C, respectively. It indicates that the age hardening process of Al–Mg–Si alloy composites is accelerated, and the aging hardness is enhanced significantly due to the addition of sub-micron alumina particles modified with rare earth Y_2O_3.

Fig. 3 shows TEM micrographs of the composites at 130 °C for different aging periods, respectively.

As shown in Fig. 3(a) (under-aged, 130 °C/3 h), Fig. 3(b) (peak-aged, 130 °C/10 h) and Fig. 3(c) (over-aged, 130 °C/100 h), it is very difficult to find dislocations and aging precipitates in the as-received alumina particles/ Al–Mg–Si alloy composites in all the aging stages, and the microstructures present the characteristics of rare dislocations and precipitations. It can be explained by the previous reports [6]. In contrast, after the surface modification of sub-micron alumina particles with Y_2O_3, the aging microstructures of modified composites have a significant difference compared to non-modified composites. At under-aged condition(130 °C/2 h), as shown in Fig. 3(d), there is a certain amount of dislocations and precipitate phases in the matrix. When the aging time reaches peak-aged time (130 °C/9 h), the large amounts of precipitates of

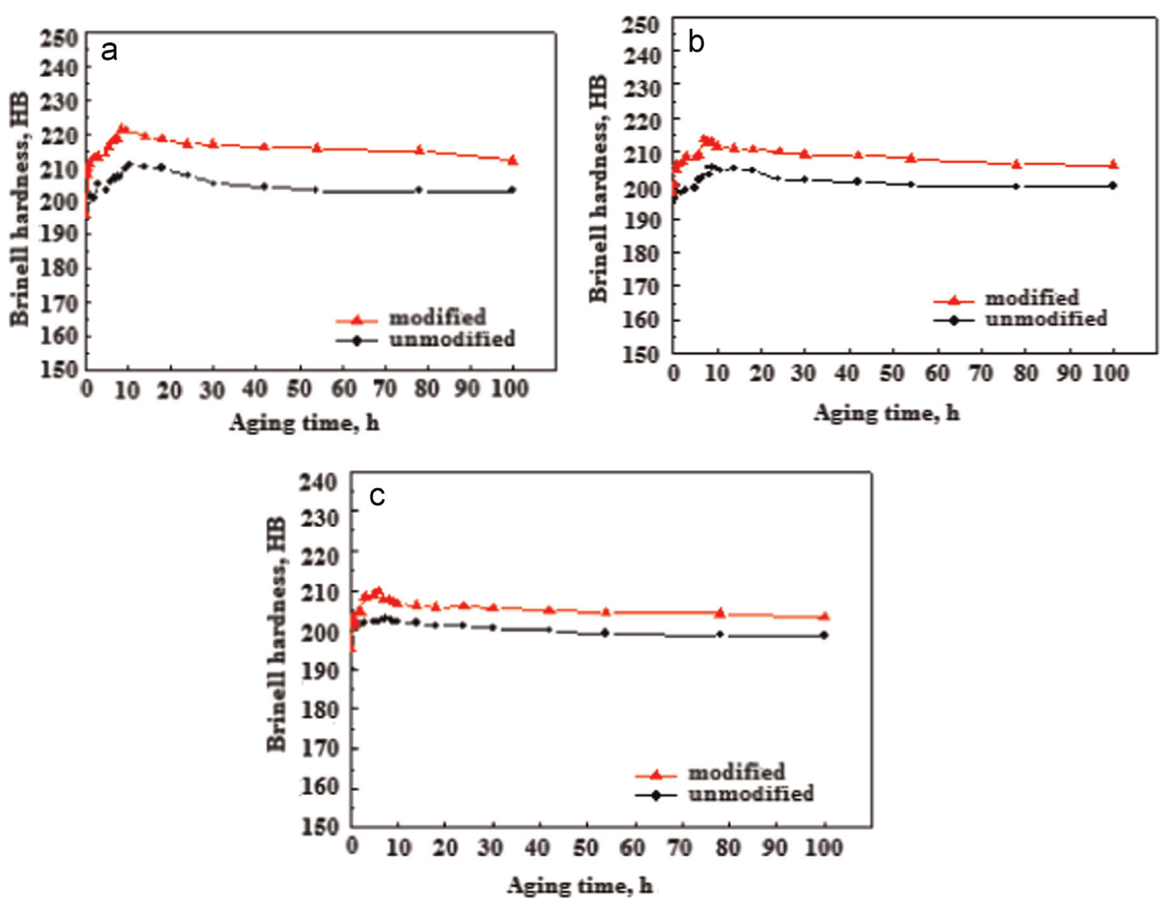

Fig. 2. Age-hardening curves of unmodified and modified Al_2O_3p/Al–Mg–Si alloy composites (30 vol%) aged at (a) 130 °C, (b) 160 °C, and (c) 190 °C.