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Effect of aging hardening on in situ synthesis magnesium matrix composites

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Abstract

Magnesium matrix composites reinforced with TiC particulates was synthesized using in situ synthesis technique. The result of XRD revealed the presence of TiC in precursor blocks and TiC/AZ91 composites. Effect of aging hardening on the composites was described using Brinell hardness measurements and scanning electron microscopy (SEM). The results revealed that the aging hardening peak of TiC/AZ91 composite appeared earlier comparatively with that of AZ91 magnesium alloy. And the appearance of aging hardening peak was earlier under the higher aging temperature such as 200 °C. The precipitating behavior of $Mg_{17}Al_{12}$ phase in AZ91 alloy and TiC/AZ91 composites was described. Little discontinuous was discovered in the composites, and the amount of continuous precipitate in the composite matrix is smaller comparatively to that of AZ91 alloy. These results were analyzed with the fine grain size, much more interface between TiC and magnesium and high-density dislocation in magnesium matrix, which was contributed to the addition of TiC particulates.

Keywords: Magnesium matrix composite; In situ synthesis technique; Aging hardness; Microstructure characterization

1. Introduction

The ability of magnesium matrix composites to exhibit high-specific mechanical properties has been instrumental in attracting the attention of manufacturers for their possible use in automobile, aerospace, space, electronics and sports industries [1–3]. The heat-treated on materials can improve mechanical properties of materials, and retain the stability of materials structure and size. So some researches have been conducted on aging behavior of magnesium matrix composites. Badini et al. [4] investigated the aging characteristics of B_4C/AZ80 composite by optical microscopy and XRD. The addition of B_4C particle increased the aging rate of the composite. Zheng et al. [5] investigated the aging characteristics of SiC_w/AZ91 composite using differential scanning calorimetry (DSC), Vickers hardness measurement, scanning electron microscopy (SEM) and transmission electron microscopy (TEM). His results exhibited an accelerated hardening response compared with the unreinforced matrix alloy. Kiehn et al. [6] studied the electrical resistivity changes due to precipitation during isochronal annealing up to 300 °C in alumina fiber-reinforced AZ91D composite fabricated by squeeze casting. In a word, these researches indicate that the aging kinetics and aging hardening efficiency during aging of these composites depend on variety of factors, such as: the size; volume fraction of reinforcement; secondary processing; temperature of aging and the nature of matrix–reinforcement interface. But these results were all conducted on magnesium matrix composites which were synthesized using extra addition methods.

Compared to extra addition methods, in situ synthesis technique is a new processing method. The in situ synthesis technique is attractive on present research, for the composites synthesized by in situ method have advanced performance due to fine reinforcements and clear interface between metal matrix and reinforcement [7–9]. Remelting and dilution (RD) technique is one of in situ synthesis technique. The RD technique contains of two steps: firstly, precursor blocks contains of reinforcements is prepared; secondly, the precursor blocks is diluted into metal matrix materials melt to synthesize composites.

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Accordingly, the TiC/AZ91 composites were synthesized using RD technique. And particular emphasis was placed to study the formation of TiC/AZ91 composites and the effect of aging hardening on microstructure and Brinell hardness of TiC/AZ91 material.

2. Experimental procedures

The composite based on 8.0 wt.% TiC/AZ91 was prepared using the process of RD technique. The process was accomplished with three steps: (1) activated powder was synthesized by ball mill; (2) activated powder was sintered; (3) the precursor blocks were diluted into magnesium matrix melt to synthesize TiC/AZ91 composites.

In the experiment, the powder of Al, Ti and graphite whose purity degree are up 99.5% and the size are less than 75 μm were used as the base materials of precursor blocks. The powder mixture containing Al, Ti and graphite was milled and treated at argon gas atmosphere protection in order to activate the powder mixture. Then the mixed powder was pressed into columniform block with 30 mm diameter and 50 mm high. After being pressed, the precursor blocks were sintered in argon gas atmosphere protection.

The pure magnesium ingot was used as the base materials. After the magnesium ingot has been molten, the precursor blocks were diluted into the molten metal. The mixture melt was stirred to facilitate the incorporation and uniform distribution of reinforcement particulates in the metallic melt. Finally, the molten metal was poured into an iron sample mould to synthesize TiC/AZ91 composites. The AZ91 magnesium alloy was synthesized using common cast method. The matrix alloy and composite were solution-treated (T4). After solution treatment, the alloy and TiC/AZ91 composite were aged at 175 and 200 °C for different periods up to 50 h. The age-hardening response of the composite and AZ91 alloy was characterized using Brinell hardness measurements. Each hardness value is the average of at least five measurements. The microstructures of the AZ91 alloy and composite were examined by Hitachi S-520 scanning electron microscope (SEM).

3. Experimental results

3.1. Phase analysis

The XRD results of precursor blocks and TiC/AZ91 composites are shown in Fig. 1. The presence of TiC and Al_2O_3 phase in precursor blocks was validated. Aluminum as the base materials was also detected in precursor blocks using XRD analysis (as shown in Fig. 1(a)). Comparatively to precursor blocks, the presence of TiC phase and new $Mg_{17}Al_{12}$ phase in TiC/AZ91 composites was confirmed by XRD analysis, but Al_2O_3 and Al phase disappeared (as shown in Fig. 1(b)). The results of EDX analysis on TiC/AZ91 composites are shown in Fig. 2. The results of EDX analysis revealed that there are 6.43 wt.% titanium, 1.58 wt.% graphite and 8.36 wt.% aluminum in TiC/AZ91 composites. It can be calculated that there was about 8.01 wt.% TiC particulates in TiC/AZ91 composites for element titanium is being in composites by mean of TiC mainly. The weight percent of aluminum in TiC/AZ91 composites was consilient with that of AZ91 magnesium alloy.

3.2. Age-hardening response

The effect of aging time on the hardness of the TiC_p/AZ91 composite and the unreinforced AZ91 matrix alloy under

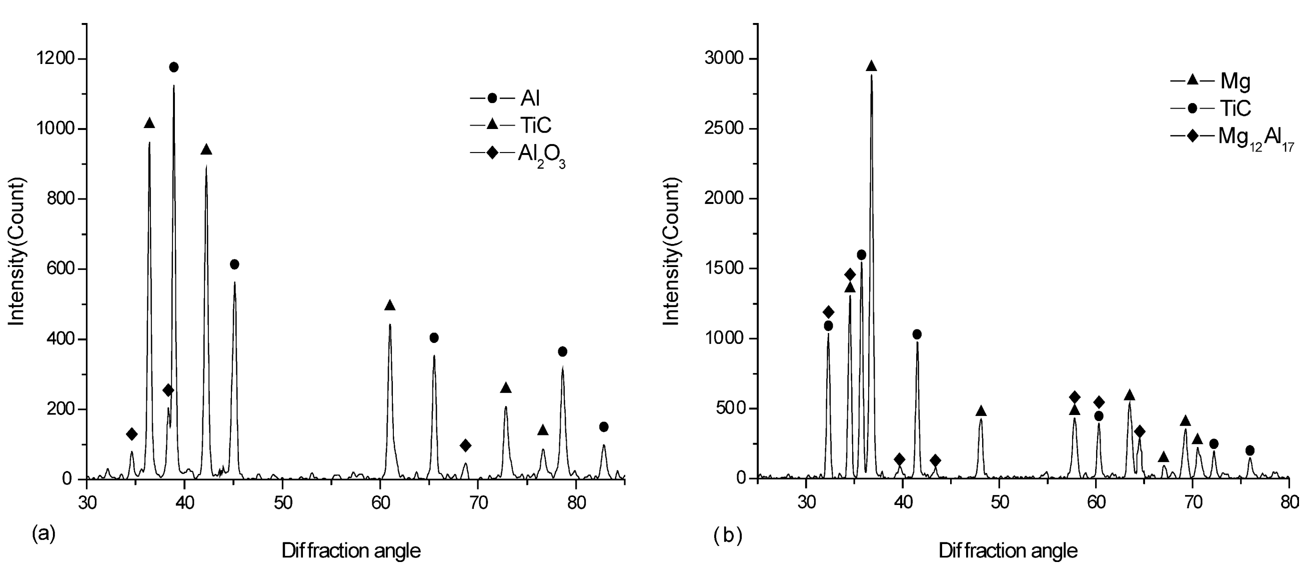

Fig. 1. XRD patterns of samples ((a) precursor blocks; (b) TiC/AZ91 composites).