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Effects of volume ratio on the microstructure and mechanical properties of particle reinforced magnesium matrix composite

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ABSTRACT

In the present study, the AZ91 alloy reinforced by (submicron + micron) SiCp with four kind volume ratio was fabricated by the semisolid stirring casting technology. The influence of volume ratio between submicron and micron SiCp on the microstructure and mechanical properties of Mg matrix was investigated. Results show that the submicron SiCp is more conducive to grain refinement as compared with micron SiCp. With the increase of volume ratio, the submicron particle dense regions increase and the average grain size decreases. The yield strength of bimodal size SiCp/AZ91 composite is higher than monolithic micron SiCp/AZ91composite. Both $\Delta\sigma_{Hall-Petch}$ and $\Delta\sigma_{CTE}$ increase as the volume ratio changes from 0:10, 0.5:9.5, 1:9 to 1.5:8.5. Among the composite with different volume ratio, the S-1.5 + 10-8.5 composite has the best mechanical properties. The interface debonding is found at the interface of micron SiCp-Mg. As the increase of volume ratio, the phenomenon of interface debonding weakens and the amount of dimples increases.

1. Introduction

In the past few decades, research and development in materials shifted from plain to composite materials, catering to the global need for reduced weight, low cost, quality and high performance in structural materials. Particle reinforced magnesium matrix composites (PMMCs) offers a remarkable mechanical properties such as high specific strength, specific modulus, high micron-hardness and good wear resistance, exhibit the advantages of lower cost, easier fabricate ability and secondary processing [1–4].

Particles have significant effect on controlling grain size, manipulating texture and enhancing load transfer effect, thus help to improve the mechanical properties of matrix [5–8]. Considerable studies have been performed regarding the microstructures and mechanical properties influenced by reinforcement size [9]. Hassan et al.'s previous study illustrated that the mechanical properties of the magnesium containing nano and submicron size particles was much higher than that of micron size particle [10]. Meanwhile, the microstructure and mechanical properties of PMMCs can also be affected by particle volume fraction [11]. On Byung-Chul Ko et al.'s investigation of micron SiCp/Mg composite, the failure strain decreases as the SiCp volume fraction increase [12]. Deng et al.'s investigation illustrated that a little amount of submicron particles can increase the yield strength and ultimate strength of composite. However, when the submicron SiCp content exceeded 2 vol%, the agglomerated regions appeared in the composites and the mechanical properties were obviously decreased [13]. The micron particles were not only distributed uniformly in magnesium matrix, but also had significant rule on refining grain size and enhancing mechanical properties. Our previous study had proved that the mixture of a little amount submicron particle and micron particle had significant influence on microstructure and mechanical properties. However, the influence of volume ratio between micron and submicron SiCp on the microstructure, mechanical properties and strengthening mechanism of Mg matrix still need further investigation. Thus, the composites reinforced by (submicron + micron) SiCp with four kinds volume ratio were fabricated, it is hoped to reveal the influence of volume ratio on the microstructure and mechanical properties of bimodal size particle reinforced magnesium matrix composite, and then determine the optimum volume ratio between micron and submicron SiC particle.

2. Experimental procedures

The chemical composition (wt.%) of the magnesium alloy used in the present is Mg–9.3Al–0.7Zn–0.23Mn–0.02Si. Two sizes

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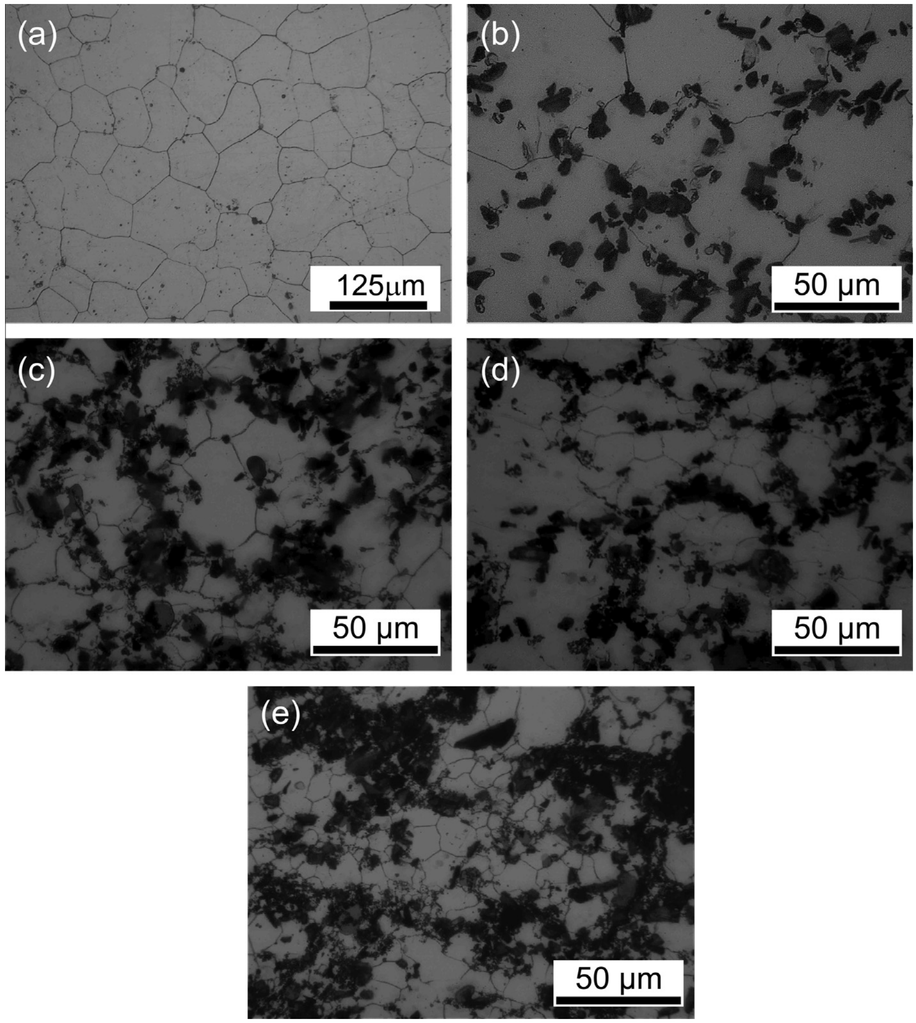

Fig. 1. OM micrographs of (a) AZ91 alloy, (b) 10-10 composite, (c) S-0.5 + 10-10 composite, (d) S-1 + 10-9 composite, (e) S-1.5 + 10-8.5 composite.

(micron and submicron) of SiCp are used as reinforcements. The average particle size of the micron and submicron SiCp is about 10 μm and 0.2 μm, respectively. In our present study, the whole volume fraction of SiCp is set as 10% and the volume fraction ratio between micron and submicron SiCp is 10:0, 9.5:0.5, 9:1 and 8.5:1.5, respectively. So the 10 μm 10% (denote as "10-10"), 10 μm 9.5% + 0.2 um 0.5% (denote as "S-0.5 + 10-9.5"), 10 μm 9% + 0.2 μm 1% (denote as "S-1 + 10-9") and 10 μm 8.5% + 0.2 μm 1.5% (denote as "S-1.5 + 10-8.5") SiCp/AZ91 composites were fabricated by stir casting. The whole fabrication process was conducted in a protective atmosphere of CO_2 and SF_6 to avoid burning. In each experiment, the AZ91 alloy was molten at 720 °C, and then cooled to 580 °C which made the matrix alloy in the semi-solid condition. As the manually mixed bimodal size SiCp were added into semi-solid melt, the mixture was stirred for 30 min. After be reheated to 720 °C, the melt was poured into a preheated steel mould (450 °C) and solidified under a 100 MPa pressure. In order to eliminate the influence of second phase, the as-cast billets were homogenized at 415 °C for 24 h.

The Microstructure observation was carried out by optical microscope (OM) and scanning electron microscope (SEM). The specimens for OM were ground, polished and then etched in acetic picral [2 ml aceticacid + 2 g picric acid + 20 ml H_2O + 100 ml ethanol (95%)]. The optical microstructure was examined by 4XC optical microscopy. The morphology and the chemical composition were investigated by MIRA 3XMU SEM equipped with energy spectrum. The tensile test was carried out on an Instron Series 5569 test machine at room temperature with the tensile rate of 0.5 mm per minute. The tensile properties of the specimens were determined in accordance with ASTM: E8/E8M-13a standards. For each material, three tensile specimens were tested.

3. Results and discussion

3.1. Microstructures

Fig. 1 shows the optical microstructures of as-cast 10-10, S-0.5 + 10-9.5, S-1 + 10-9 and S-1.5 + 10-8.5 SiCp/AZ91 composites.

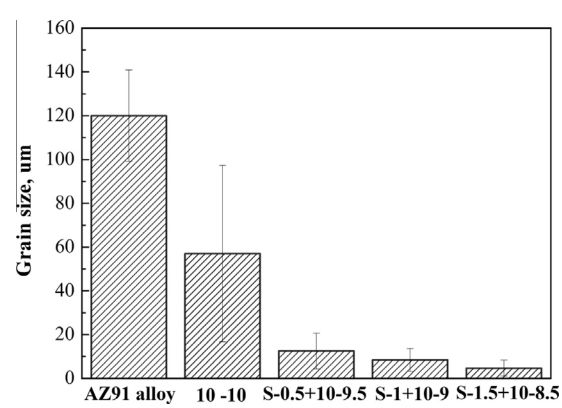

Fig. 2. The average grain sizes of SiCp/AZ91 composites.