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Effects of $Mg_2B_2O_5$ whiskers on microstructure and mechanical properties of AZ31B magnesium matrix composites

Y.P. Zhu[a,*], P.P. Jin[a,*], W.D. Fei[a,b], S.C. Xu[c], J.H. Wang[a]

[a] National Engineering Research Center of High Performance Light Metal Alloys and Forming, Qinghai University, Xining 810016, PR China
[b] School of Materials Science and Engineering, Harbin Institute of Technology, Harbin 150001, PR China
[c] Key Laboratory of Functional Materials Physics and Chemistry of the Ministry of Education, Jilin Normal University, Siping 136000, PR China

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ABSTRACT

The AZ31B matrix composites reinforced with different volume fractions (1.0, 3.5 and 6.0 vol%) of $Mg_2B_2O_5$ whiskers were fabricated by stir casting. The microstructure, reinforcement distribution and texture evolution of the as-extruded specimens were investigated by optical microscopy, transmission electron microscopy, scanning electron microscopy, and X-ray diffractometer. Microstructure characterization revealed relatively uniform distribution of reinforcement and significant grain refinement in the composite samples. It was found by X-ray diffractometer analyses that a typical fiber texture with (0002) basal plane parallel to the extrusion direction formed in both AZ31B alloys and $Mg_2B_2O_5$w/AZ31B composites. The $Mg_2B_2O_5$ whiskers could weaken the texture and the fiber texture intensity decreases as the $Mg_2B_2O_5$ whiskers volume fraction increases. Tensile tests along the extrusion direction were carried out at room temperature. It is the first time to find that the presence of $Mg_2B_2O_5$ whiskers reinforcement could improve both the strength and elongation of AZ31B matrix composites with low volume fraction of $Mg_2B_2O_5$ whiskers.

1. Introduction

Magnesium alloys are well known for their low density, high specific strength and superior damping capability [1–3]. However, they are often limited by unsatisfactory mechanical properties. To meet the challenge of growing demand for light structural applications and in terms of economic considerations, metal matrix composites (MMCs) reinforced with discontinuously reinforcement (particle, whisker or short fiber) have attracted more attention [4–6].

In the past decades, micro to nano sized particle reinforced magnesium matrix composites [6–18] are especially attractive due to their isotropic behavior. The mechanical properties of the composite are much promising if the dispersoid particlesare of nano-size since both the strength and the ductility can be improved [12]. However, no agreed conclusions were adopted on the improvement in both the strength and the ductility of nanoparticles reinforced magnesium composites [13–16]. Furthermore, the higher cost of nano particles processing and the fabrication of nano composite limit their application. Whisker is fiber shaped and defect-free single crystal [19]. It has superior mechanical property, and is one of the strongest materials. It is worth to study the metal borates whisker reinforced magnesium composites owing to their lower cost and potential for light structural application. In general, tensile strength of the MMCs fabricated by typical processes, such as powder metallurgy [19,20] and squeeze casting [21,22], were improved, but their elongations were deteriorated dramatically when high volume fractions of the whiskers were added, typically 10–50 vol%. The undesirable poor ductility might limit the applications of magnesium matrix composites. It was reported that the SiC particles [7] and Y_2O_3 particles [18] could weaken the extruded fiber texture in magnesium matrix alloy. Furthermore, a weak texture is known to promote ductility [23]. Therefore, if a combination of whisker reinforcement and weak texture could be achieved, it would be possible to improve both the strength and the ductility of a composite.

The aim of this study is to investigate the mechanical properties of AZ31B composites with different volume fractions of $Mg_2B_2O_5$ whisker, and the effects of their texture and microstructure. To the best of our knowledge, there is no attempt being made to fabricated $Mg_2B_2O_5$w/AZ31B composites by stir casting, and report on their mechanical properties is also lack in the literature. New results shown in the present work is contribution in the field for the first time.

2. Experimental procedures

In this study, the matrix alloy was AZ31B magnesium alloy (3.0%

* Corresponding authors.
E-mail addresses: zyphb2012@live.cn (Y.P. Zhu), jinpeipeng@hotmail.com (P.P. Jin).

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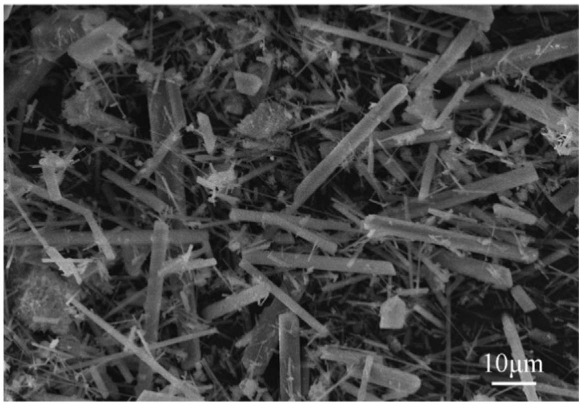

Fig. 1. SEM image showing the morphology of $Mg_2B_2O_5$ whiskers.

Al, 0.8% Zn, 0.1%Mn, balance Mg). The reinforcement was $Mg_2B_2O_5$ whisker with diameter of 0.2–2.0 μm and length of 20–50 μm. The morphology of $Mg_2B_2O_5$ whiskers is shown by SEM image in Fig. 1. The $Mg_2B_2O_5$ whiskers reinforced AZ31B magnesium matrix composites (abbreviation for the $Mg_2B_2O_5$w/AZ31B) with1.0%, 3.5% and 6.0% volume of reinforcements were fabricated by stir casting process. The AZ31B magnesium was melted at 700 °C for 30 min. Then, the $Mg_2B_2O_5$ whiskers were added into the melt, and stirred for 30 min. The melt was poured into a steel mold preheated to 400 °C, and cooled down. The AZ31B alloy and $Mg_2B_2O_5$w/AZ31B composites ingots were machined into cylindrical billets with diameter of 30 mm×70 mm. Then, the billets were extruded at 350 °C with an extrusion ratio of 9.5:1.

Microstructure characterization was carried out by optical microscopy (OM), scanning electron microscopy (SEM) and a transmission electron microscopy (TEM). Metallurgical specimens for OM and SEM were cut parallel to extrusion direction, and then was polished and etched by acetic-picric acid. The distribution of reinforcement and the fracture surface of tensile tested sample were observed by SEM. Samples for TEM observation were thinned by the ion milling. The texture was measured using a Philips X′Pert diffractometer. The incomplete (0002), $(10\bar{1}0)$, $(10\bar{1}1)$, $(10\bar{1}2)$ pole figures were measured. The complete pole figures were calculated using the texture analysis software. The irradiated surface was parallel to extrusion direction.

Tensile tests were performed at room temperature using Instron 5569 tensile testing machine with a tensile rate of 1 mm/min. The tensile specimens with gauge length of 30 mm and diameter of 5 mm were machined with tensile axis along the extrusion direction.

3. Results and discussion

3.1. Microstructure

SEM micrographs in Fig. 2 show the distributions of $Mg_2B_2O_5$ whiskers in extruded composites. It can be seen that the $Mg_2B_2O_5$ whiskers are arranged parallel to extrusion direction, owing to the whiskers rotating with matrix during extrusion. Fig. 2(a) illustrates relatively uniform distribution of $Mg_2B_2O_5$ whiskers in composite with 1 vol% reinforcement. With increased whiskers volume, the whisker distribution appears a little agglomerated. When the amount of reinforcement is increased to 6.0 vol%, the agglomerate regions formed in the composite, as shown in Fig. 2(c). In addition, the broken whiskers were observed, as indicated by arrow in Fig. 2(c), which is due to the stress concentration at matrix/reinforcement interface.

Optical images in Fig. 3 illustrate the microstructures of extruded AZ31B alloy and $Mg_2B_2O_5$w/AZ31B magnesium matrix composites, and the corresponding area-weighted grain size distributions are shown in Fig. 4. It can be seen that the nearly equiaxed grains are

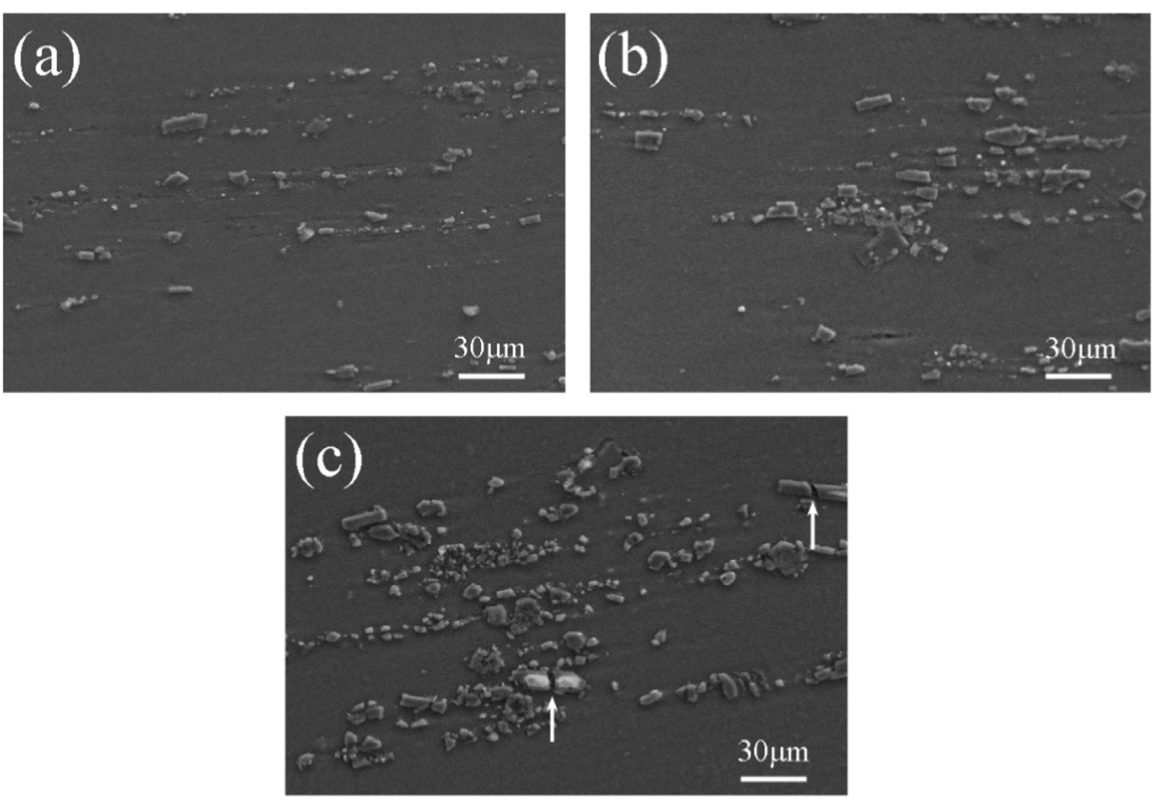

Fig. 2. SEM micrographs showing the distributions whiskers inas-extruded $Mg_2B_2O_5$w/AZ31B composites: (a) 1.0 vol%, (b) 3.5 vol% and (c) 6.0 vol% $Mg_2B_2O_5$ whiskers.