Journal of Alloys and Compounds 487 (2009) 293–297

Contents lists available at ScienceDirect

Journal of Alloys and Compounds

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

The effect of Ba addition on microstructure of in situ synthesized Mg_2Si/Mg–Zn–Si composites

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ARTICLE INFO

Article history:
Received 10 February 2009
Received in revised form 17 July 2009
Accepted 20 July 2009
Available online 28 July 2009

Keywords:
Mg_2Si
Ba addition
Microstructure
Modification
Heterogenous nucleation

ABSTRACT

In order to modify in situ synthesized Mg_2Si phase in Mg–6Zn–4Si alloy, Ba addition of 0.1–3.0 wt.% had been explored. The effect of Ba addition on the microstructure of Mg_2Si/Mg–Zn–Si composites was investigated by means of optical microscope, scanning electron microscope, X-ray diffraction and energy dispersive spectrometer. The results indicate that the morphology of primary Mg_2Si in the composites changes from large dendrite to fine polygon with the increasing Ba content. The average size of primary and eutectic Mg_2Si sharply decreases with increasing Ba content up to 1.0 wt.% and then slowly increases. Theoretical calculation and experimental analysis show that tiny $BaMg_2Si_2$ particles, formed by adding Ba, act as the heterogenous nucleation substrates for primary Mg_2Si. Therefore, Si consumption due to $BaMg_2Si_2$ formation and primary Mg_2Si nucleation results in the inhibition of Mg_2Si growth. It is also found that the $BaMg_2Si_2$ phase in primary Mg_2Si is obviously coarsened as Ba content exceeds 1.5 wt.% and some needle-like $Ba_2Mg_3Si_4$ is found in alloy with 3.0 wt.% Ba. These are responsible for the over modification effect. Therefore, it can be concluded that proper Ba addition can effectively modify and refine primary Mg_2Si and decrease the amount of eutectic Mg_2Si.

1. Introduction

In recent years, in situ synthesized Mg matrix composites are considered to have great potential in modern industries due to their excellent heat-resistance and creep-resistance, low density and high specific strength as well as better cohesion between the reinforcement and matrix [1–3]. One research hotspot is in situ synthesized intermetallic compound Mg_2Si reinforced Mg matrix composite [3,4]. Mg_2Si is characterized by high melting temperature of 1085 °C, low density of $1.99 \times 10^3\,kg\,m^{-3}$, high hardness of $4.5 \times 10^9\,N\,m^{-2}$, low thermal expansion coefficient of $7.5 \times 10^{-6}\,K^{-1}$ and high elastic modulus of 120 GPa [5], which greatly improve the heat-resistance and wear-resistance of the alloys.

However, a mass of coarse-dendritical primary Mg_2Si (with size even exceeding 100 μm) and bulk-Chinese-character eutectic Mg_2Si appearing in high-Si magnesium alloys, deteriorate the mechanical and deformation properties of materials and impede their applications [6,7]. How to modify Mg_2Si phase in high-Si magnesium alloy has attracted considerable attention. Various processing techniques have been employed, such as mechanical alloying [1], hot extrusion [2,8], heat treatment [9], rapid solidification [10,11], and modification treatment [12–15]. Among those methods, modification during solidification process of alloys is a relatively convenient and economical method. For example, the primary Mg_2Si dendrite was changed to polyhedral particles with size about 20 μm when Y, KBF_4, B_2O_3 and Bi were added to Mg–Si alloy, and the modification mechanism can be regarded as poisoning [12–14]. It is also reported that the combination of Sr–Sb modification and heat treatment can alter the primary Mg_2Si dendrite to short rod-shape or granular [9]. But most of those researches focused on the variation of primary Mg_2Si. It is necessary to develop more effective modifier in order to modify both the primary Mg_2Si dendrite and Chinese-characters-like eutectic Mg_2Si.

It is well known that Al–Ba alloy has been used to modify the primary Si in Al–Si alloy. Considering the similarity between Si modification in Al–Si alloy and Mg_2Si modification in Mg–Si alloy, Ba may be a good modifier for Mg_2Si in Mg–Si alloys. The objectives of this work are to find out the effect of Ba addition on the microstructure of Mg–6Zn–4Si alloy, to explore the modification mechanism of Ba modifier on in situ synthesized Mg_2Si during solidification processing, and to prepare Mg matrix composites with fine microstructure.

2. Experimental

2.1. Raw materials and smelting

Commercial Mg ingot (>99.9 wt.%), Zn ingot (>99.8 wt.%) and Si (>99.8 wt.%) were used to prepare master alloy Mg–6Zn–4Si. Mg and Zn ingots were melted up to 700 °C

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doi:10.1016/j.jallcom.2009.07.111

Table 1
Experimental alloy number and nominal Ba addition.

Alloy No.	0	1	2	3	4	5	6
Ba content (wt.%)	0	0.1	0.5	1.0	1.5	2.0	3.0

in a steel crucible, and then Si particles were added. The melt was continuously heated to above 750 °C and kept for 20 min. The melt was well-proportioned by mechanical agitation for 5 min and deslaged, then cast into a steel mould which was preheated at 250 °C while the melt temperature is below 700 °C. The master alloy ingots were sliced for subsequent experiments.

Rationed amount of pure Ba (>99 wt.%) was added to remelted master alloys. Then the melts were kept at 750 °C for 15 min. After being stirred and deslaged, the melts were cast into the preheated steel mould (with the size of 100 mm × 80 mm × 20 mm). The whole smelting was carried on in an electric resistance furnace and protected by the gas mixture of 1 vol.% SF_6 + 99 vol.% CO_2. The Ba contents of ingots are shown in Table 1.

2.2. Microstructure investigation

After kibbled and polished, samples cut from the middle of castings were etched by 0.4 vol.% nitric alcohol solution. XJP-300 Optical Microscope (OM) was used to observe the microstructure of the samples. The average areas of primary Mg_2Si grains in every optical image were measured by Image-pro Plus 5.0 software. The crystal structures and chemical composition of phases were detected and analyzed by Bruker D8-advance X-ray diffraction (XRD) and energy dispersive spectrometer (EDS) affiliated to the LEO 1550 scanning electron microscope (SEM), respectively.

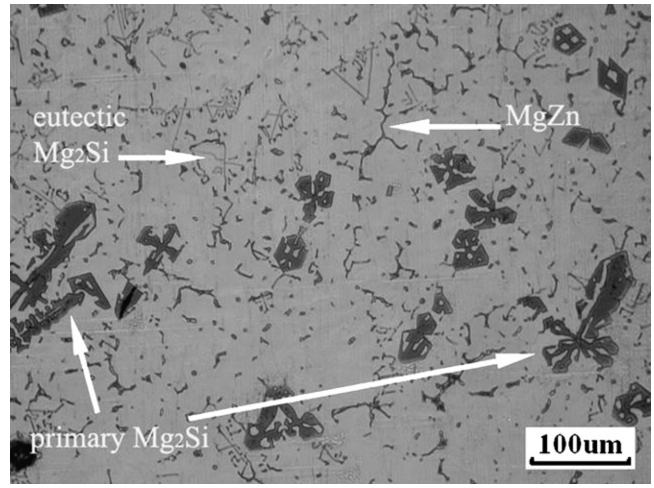

Fig. 1. Microstructure of alloy 0.

3. Results

The microstructure of Mg–6Zn–4Si master alloys is consisted of primary Mg_2Si, eutectic Mg_2Si, intermetallic compound MgZn

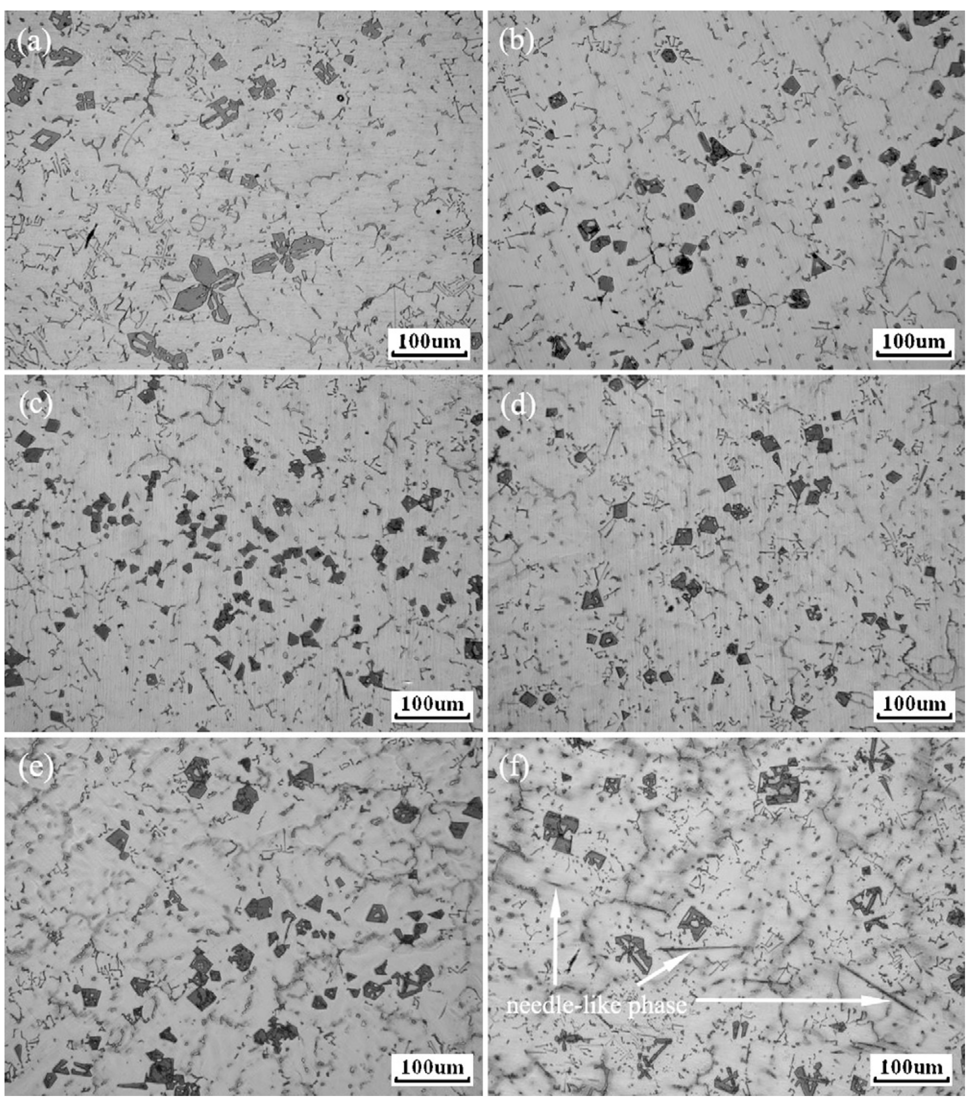

Fig. 2. OM of contained Ba alloys: (a) alloy 1, (b) alloy 2, (c) alloy 3, (d) alloy 4, (e) alloy 5 and (f) alloy 6.