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Microstructure and mechanical properties of Mg–8Li–2Zn–0.5(Ce, Y) alloys

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ABSTRACT

0.5 wt.% Ce and Y were added into the alloy of Mg–8Li–2Zn, respectively. The different behaviors of Ce and Y in the alloy were investigated. Results show that, Ce and Y can both refine the α phase, and the α phase was spheroidized. Two kinds of compounds exist in the alloy when the alloy contains Ce/Y. They are Zn_2Ce and Mg_6Y, respectively. Zn_2Ce mainly distributes at the grain boundary of the alloy with the shape of blocky. Mg_6Y mainly distributes in the inner place of grains with the shape of granular. The size of Zn_2Ce is much larger than that of Mg_6Y. Y and Ce are both favorable for the improvement of strength, and the effect of Y is more obvious. The addition of Ce makes the elongation of the alloy become poor, while the addition of Y can increase the elongation of the alloy.

1. Introduction

The superlight property of Mg–Li base alloy has been attracting more and more concerns. To improve the strength of Mg–Li alloys, Al and Zn are often used as alloying elements for their obvious solid solution strengthening effects [1,2]. The density of Al is close to that of Mg. Therefore, the Mg–Li–Al alloys have been researched detailedly [3,4]. The density of Zn is relatively larger than that of Al and Mg, but the addition of Zn in Mg–Li alloys is favorable for the deformation properties of alloys. Accordingly, to achieve wrought Mg–Li alloys with high properties, the Mg–Li–Zn alloys are being researched more and more widely [5,6]. Among the wrought Mg–Li base alloys, the most of them are the alloys with two-phase matrix structure (α magnesium solid solution and β lithium solid solution) because the two phases can coordinate with each other during deformation process. The Mg–Li base alloys with two-phase matrix structure have a lithium content of 5.7–10.3 wt.% [7].

Besides the elements of Al and Zn, some other alloying elements, such as Mn, Ca, Ag, Sn, Cd, RE (rare earth elements) et al., have been also used in the alloys of Mg–Li–Al or Mg–Li–Al–Zn [8–10]. However, there are few reports about the addition of above elements in Mg–Li–Zn alloys [11].

In this paper, the Mg–8Li alloy was chosen as the research subject. 2 wt.% Zn was added into the alloy as the third pivot element. Additionally, 0.5 wt.% Ce or Y was added into the alloy. The effects of the additions on the microstructure and mechanical properties were investigated.

2. Experimental materials and procedures

The materials used in this experiment include commercial pure magnesium ingot, commercial pure zinc ingot, commercial pure lithium ingot, Mg–26 wt.%Y master alloy and Mg–28 wt.%Ce master alloy. The charges of the designed alloys were loaded in a pure graphite crucible mounted in a medium-frequency induction furnace. After the furnace chamber was pumped to a vacuum state, pure argon was input into the chamber as a protective gas. Subsequently, the charges were heated and melted, and the melt was poured into a permanent casting mould, which was placed in the furnace chamber beforehand. The compositions of as-cast alloys were measured with inductively coupled plasma mass spectrometry (ICP-MS). The designed compositions and measured results are listed in Table 1.

The microstructure of the alloys was observed with optical microscope (OM) and scanning electron microscope (SEM). Before observation, the specimens were polished and etched with an etchant of 3 vol.% nital. To determine the compounds distributing in the matrix, energy dispersive X-ray spectroscope (EDS) was used to measure the compositions of the compounds. The mechanical properties of the alloys were charactered with tensile testing. During tensile testing, the tensile speed was 2 mm/min.

3. Results and discussions

3.1. Microstructures of the alloys

The microstructures of the as-cast specimens are shown in Fig. 1. Mg–8Li alloy consists of two phases. The white and gray phases are α(Mg) and β(Li), respectively [12]. The addition of 2 wt.% Zn does not change the constitution of phases. The solid solubilities of Zn in the α(Mg) and β(Li) are both high. 2 wt.% Zn can be soluted into the

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Table 1
The designed compositions and measured results of the alloys, wt.%.

Designed composition	Measured composition
Mg–8Li	Mg–8.07Li
Mg–8Li–2Zn	Mg–7.74Li–1.73Zn
Mg–8Li–2Zn–0.5Ce	Mg–8.15Li–2.06Zn–0.55Ce
Mg–8Li–2Zn–0.5Y	Mg–7.89Li–2.03Zn–0.58Y

α(Mg) and β(Li) entirely [13]. Additionally, the volume fraction of α(Mg) phase increases with the addition of Zn, as shown in Fig. 1(b). The shape of α(Mg) phase in Mg–8Li and Mg–8Li–2Zn is long strip. The additions of Ce and Y both refine the α(Mg) phase, and the long strip shape α(Mg) phase is changed to shorter plate, as shown in Fig. 1(c) and (d).

To detailedly investigate the change of microstructure after the addition of Ce and Y, SEM images of the alloys are shown in Fig. 2. In the alloy of Mg–8Li–2Zn–0.5Ce, blocky compounds that precipitate along the grain boundaries can be observed, as shown in Fig. 2(a). In the alloy of Mg–8Li–2Zn–0.5Y, granular compound distributes in the inner places of grains, as shown in Fig. 2(b). The EDS results for the compounds in the two alloys are shown in Fig. 3. In Fig. 3(a), the compound can be determined as Zn_2Ce according to the atomic ratio of Zn to Ce (the Mg content may come from the matrix). In the Ce–Zn binary equilibrium phase diagram, Zn_2Ce phase exists when the Zn content is about between 30 and 50 wt.%. In this alloy, the content ratio of Zn to Ce is 4. Despite of Zn content disoluted in α and β phases, the content ratio of Zn to Ce may fall into the range of 3/7–1. Therefore, the existence of Zn_2Ce phase is reasonable. The granular compound in Mg–8Li–2Zn–0.5Y can be determined

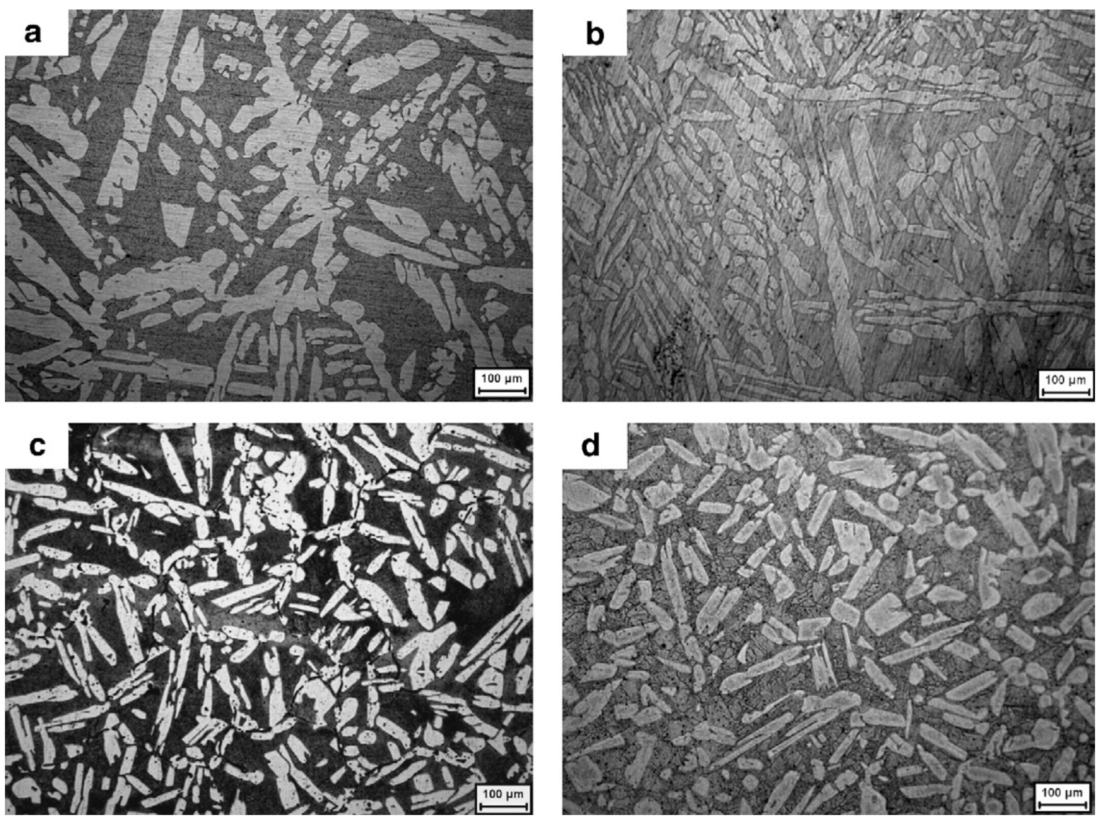

Fig. 1. Microstructures of the alloys (a) Mg–8Li; (b) Mg–8Li–2Zn; (c) Mg–8Li–2Zn–0.5Ce; (d) Mg–8Li–2Zn–0.5Y.

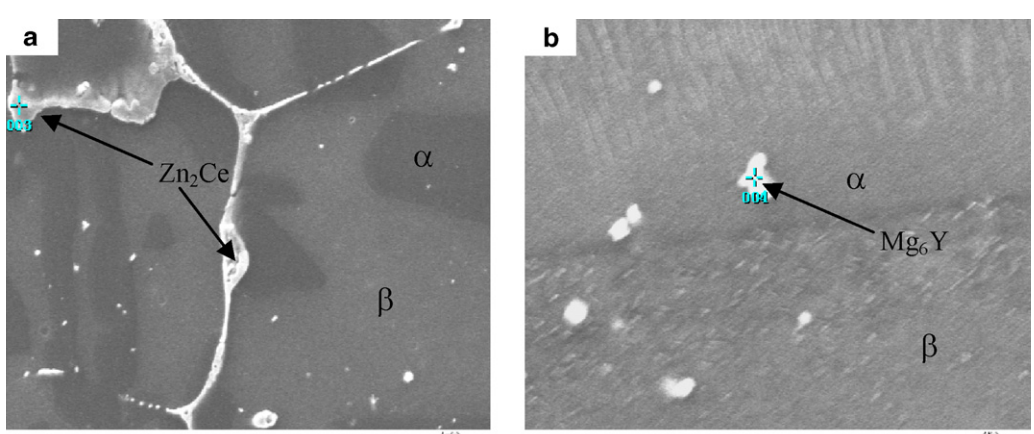

Fig. 2. SEM images of Mg–8Li–2Zn–0.5Ce (a) and Mg–8Li–2Zn–0.5Y (b).

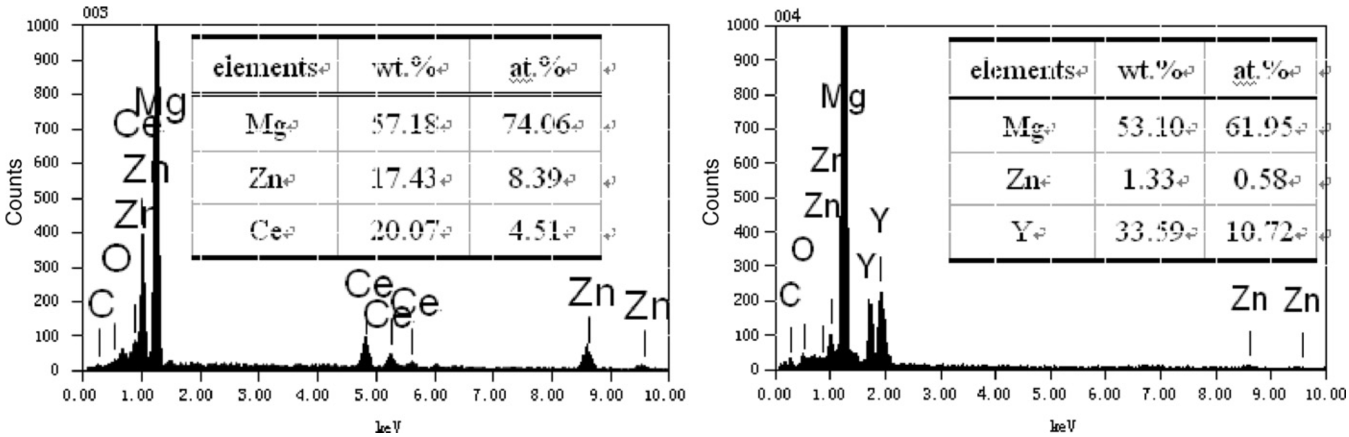

Fig. 3. EDS results of the compounds in the alloys of Mg–8Li–2Zn–0.5Ce (a) and Mg–8Li–2Zn–0.5Y (b).

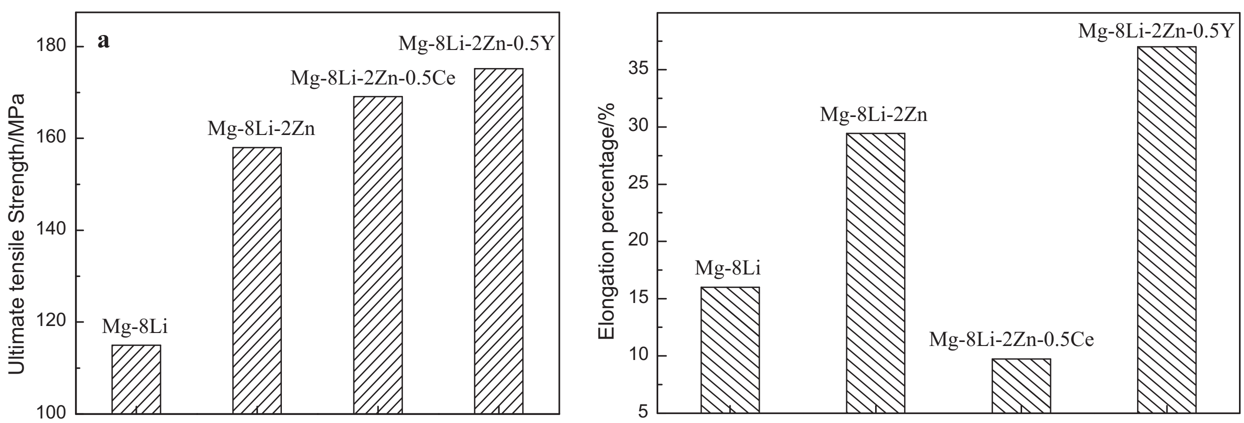

Fig. 4. Strength (a) and elongation (b) of the alloys.

as Mg_6Y (the Zn content may come from the solid soluted Zn in the matrix or in the compound of Mg_6Y). According to the Mg–Y binary equilibrium phase diagram, when Y content is less than about 50 wt.%, there will exist $Mg_{24+x}Y_5$ phase. Accordingly, Mg_6Y exists in this alloy is also reasonable (when x is 6, $Mg_{24+x}Y_5$ will become Mg_6Y).

3.2. Mechanical properties of the alloys

The strength and elongation of the four alloys investigated in this paper are shown in Fig. 4. The addition of Zn in Mg–8Li makes the strength and elongation both increase. 2 wt.% Zn in Mg–8Li not only dissolves in α and β, but also increases the fraction of α solution and refines the α solution. The additions of 0.5 wt.% Ce and 0.5 wt.% Y can both increase the strength further, and the strength of Mg–8Li–2Zn–0.5Y is higher than that of Mg–8Li–2Zn–0.5Ce. As for the elongation, the addition of Y is favorable for it, while the addition of Ce makes the elongation become very poor. The additions of Ce and Y both refine the α solution and make some compounds form in the alloy. In Mg–8Li–2Zn–0.5Ce, the blocky Zn_2Ce distributing along the grain boundaries deteriorates the elongation. Since the granular Mg_6Y distributes in the inner places of grains and its size is much smaller than that of Zn_2Ce, Mg_6Y is favorable for the elongation, while Zn_2Ce is unfavorable for the elongation.

4. Conclusions

The addition of 2 wt.% Zn increases the fraction of α solution and refines the α solution. Ce and Y both refine the α(Mg) phase, making the shape of α(Mg) phase change from long strip to shorter plate. The blocky Zn_2Ce distributes along the grain boundaries in Mg–8Li–2Zn–0.5Ce. In Mg–8Li–2Zn–0.5Y, the granular Mg_6Y exists in the inner places of grains.

The addition of 2 wt.% Zn in Mg–8Li increases both the strength and elongation. The additions of 0.5 wt.% Ce and Y in Mg–8Li–2Zn increase the strength further, and the improvement of strength for Mg–8Li–2Zn–0.5Y is more obvious than that for Mg–8Li–2Zn–0.5Ce. The addition of 0.5 wt.% Y in Mg–8Li–2Zn can make the elongation increase, while the addition of 0.5 wt.% Ce deteriorates the elongation of the alloy.

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