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Analyses of impurities in cast magnesium-rare earth elements alloys

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Abstract

Microstructure analyses of impurities in binary Mg–3%RE and Mg–8%RE alloys are presented. Light microscopy and scanning electron microscopy (SEM+EDX) techniques were used to characterize the investigated material. In microstructure, besides α-Mg solution and α+$Mg_{12}RE$ eutectic, some intermetallic compounds with different morphology (needle-like, square-like) were observed. X-ray phase analyses showed that intermetallic compounds were RE_3Si_2 and $RE_2Fe_{14}Si_3$. Their location in axis of primaryα-Mg dendrites suggests that some parts of them may act as heterogeneous nucleation sits for magnesium.

Keywords: Magnesium alloy; Rare earth elements; Microstructure

1. Introduction

The need for reduction of weight and fuel consumption has stimulated increasing interest in magnesium alloys due to their potential applications for automotive industry in the form of die-cast elements [1, 2]. The widely used magnesium alloys belong to Mg-Al series (mainly AZ and AM). However the use of these alloys has been limited because of their poor heat and corrosion resistance. These properties are improved in alloys which contain the addition of rare earth elements (RE) . Rare earth elements can form thermal stability phases such as $Mg_{12}Ce$, $Mg_{12}Nd$ or $Mg_{24}Y_5$ which can strengthen grain boundaries. The most successful of developed magnesium alloys have been those based on the Mg–RE system designated as WE43, WE54, QE22, MRI or MEZ [3-7].

In the previous paper microstructure analyses of experimental Mg–3%RE and Mg–8%RE alloys were reported [8]. In the present study impurities which are present in as-cast experimental Mg–3%RE and Mg–8%RE alloys are presented.

2. Experimental material and procedures

The nominal composition of the studied alloys are Mg–3%RE and Mg–8%RE. Rare earth elements (RE) were added in the form of cerium - rich mish metal with the approximate composition: 54.8% Ce, 23.8% La, 16.0% Nd, 5.4% Pr, 0.16% Fe, 0.19% Mg. Details concerning the preparation of alloys were described in Ref. [8]. The experimental alloys were gravity cast into metal moulds.

The specimens were prepared by the standard technique of grinding and polishing followed by etching in a solution of 1% nitric acid in alcohol. Microstructural examination was performed in a Jeol-5400 scanning electron microscope (SEM) operating at 30 kV. Analyses of alloying elements distribution were carried out by use of energy-dispersive X-ray spectrometer (EDX) at 20 kV. Phase constitutions of alloys were analyzed by X-ray diffraction (XRD). The Co Kα X-ray radiation was used.

3. Results and discussion

As-cast microstructure of Mg–3%RE and Mg–8%RE alloys had a dendritic microstructure characterized by dendrites of primary α phase (Mg) and α+$Mg_{12}RE$ partially divorced eutectic which was reported earlier [8]. Observations of microstructure of Mg–3%RE alloy revealed the presence of impurities in the form of intermetallic compound with a needle-like morphology. Fig. 1 presents secondary electron image with X-ray linear analysis of the observed phase.

Analyses of linear distribution of alloying elements through observed phases revealed a high concentration of rare earth elements and silicon. The same result was obtained from a point analysis (Fig. 1). Silicon was not an alloying element added purposely to the investigated alloy. Needle-like impurities must have formed during fabrication process of alloys.

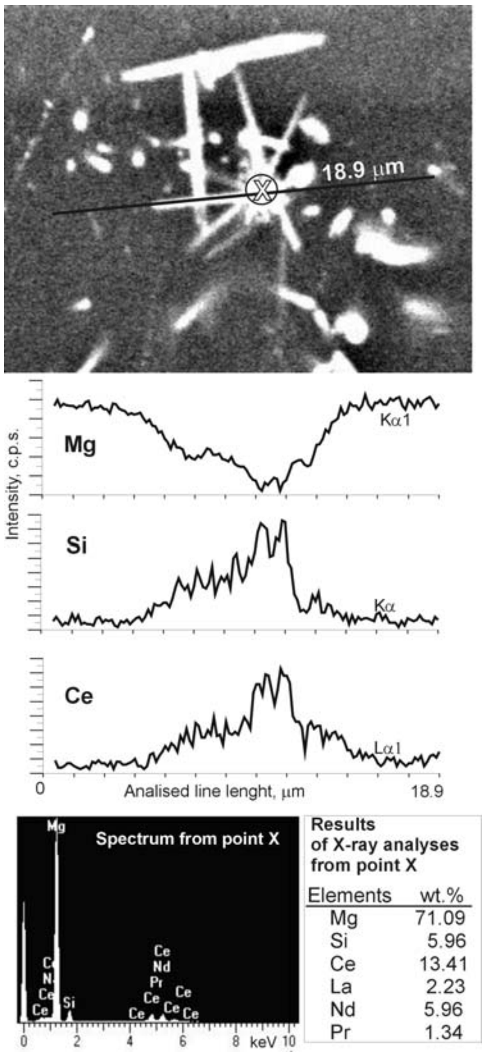

Fig. 1. SEM image of Mg–3% RE alloy with variation of elements along the scanning line; SEM+EDX

In microstructure of Mg–8%RE alloy, some intermetallic compounds with various morphology (needle-like, square-like) were observed. Figs. 2 and 3 present impurities observed in microstructure of Mg–8%RE alloy.

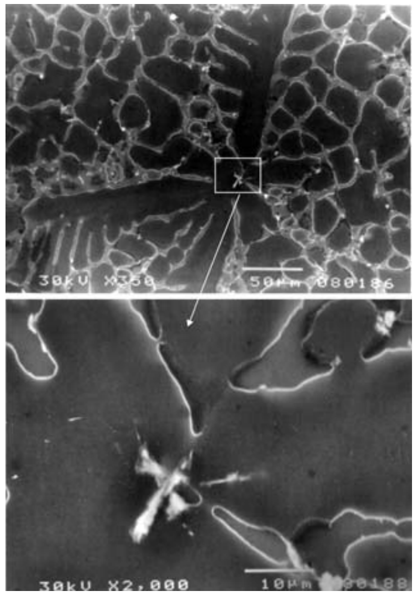

Fig. 2. Microstructure of as-cast Mg–8%RE alloy; SEM

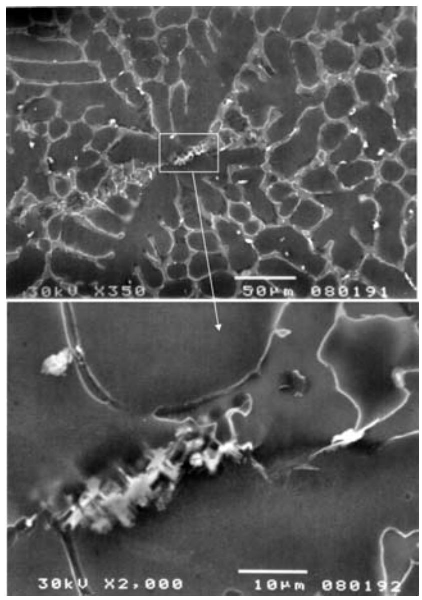

Fig. 3. Microstructure of as-cast Mg–8%RE alloy; SEM

Fig. 4 shows EDX analyses of alloying elements linear distribution and results of a point analysis obtained from observed needle-like impurity in Mg–8%RE alloy. In this case a high concentration of rare earth elements, silicon and also iron was revealed. The same result was obtained from impurity with a different morphology, presented in Fig. 5. Silicon and iron come from contamination during fabrication process of an alloy.

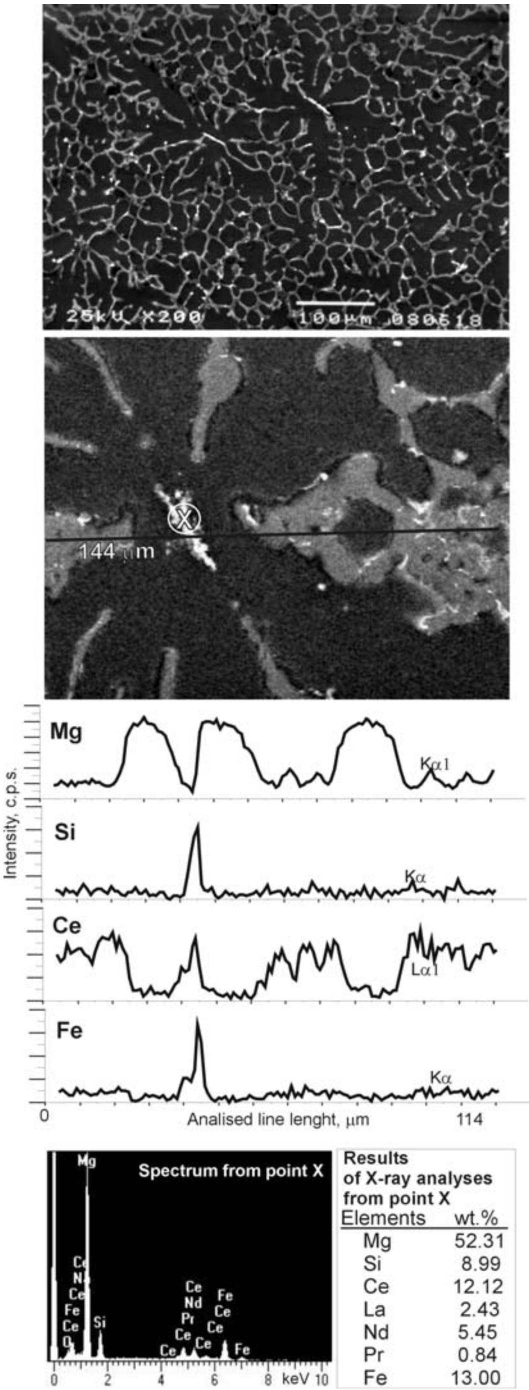

Fig. 4. Secondary electron images of Mg–8%RE alloy with variation of elements along the scanning line; SEM+EDX

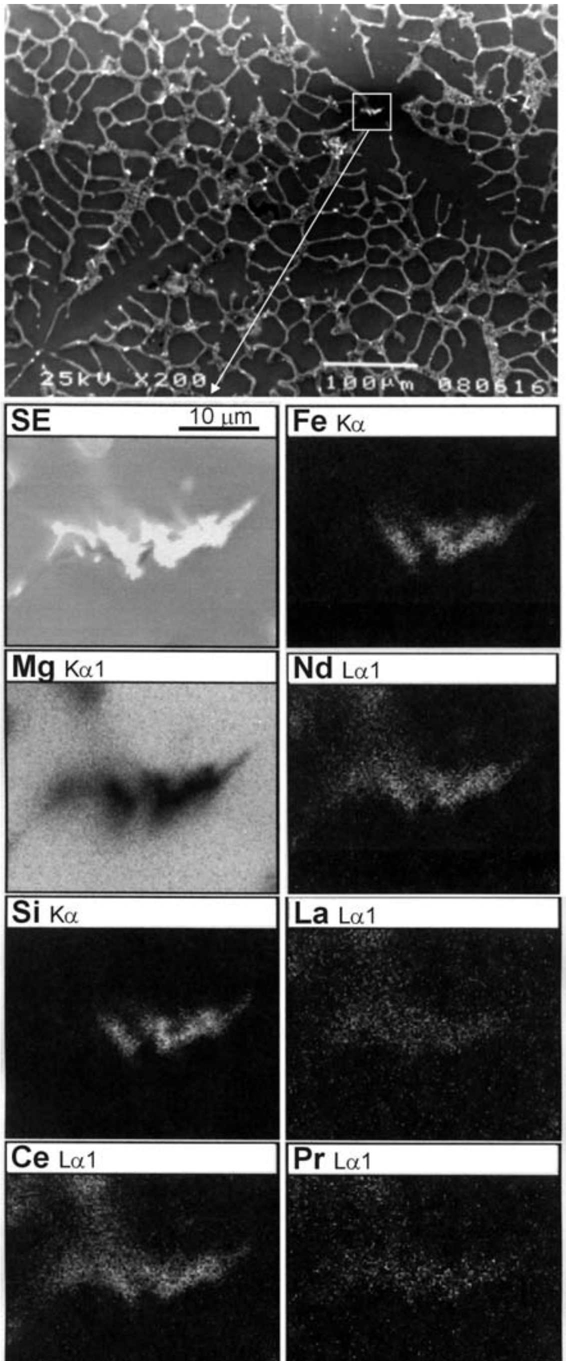

Fig. 5. Secondary electron images of Mg–8%RE alloy with surface distribution of elements; SEM+EDX

X-ray diffraction patterns obtained from investigated materials are presented in Fig. 6. In both cases, the presence of Mg-α phase and $Mg_{12}RE$ type intermetallic compounds corresponding to the formula $Mg_{12}Ce$, were revealed. Additionally, positions of peaks originating from magnesium are exactly corresponding to magnesium standard. It is suggested, that solid solubility of rare earth elements in α phase is practically zero. In the microstructure of Mg–3%RE alloy the RE_3Si_2 intermetallic compound was revealed, whereas in the Mg–8%RE alloy the $RE_2Fe_{14}Si_3$ type intermetallic compound was also disclosed. It should also be noted that analyzed impurities were very often located inside dendrites – in axis of dendrites (Figs. 1-5). This suggested that some parts of the observed intermetallic compounds may act as nucleation sits for magnesium primary phase.

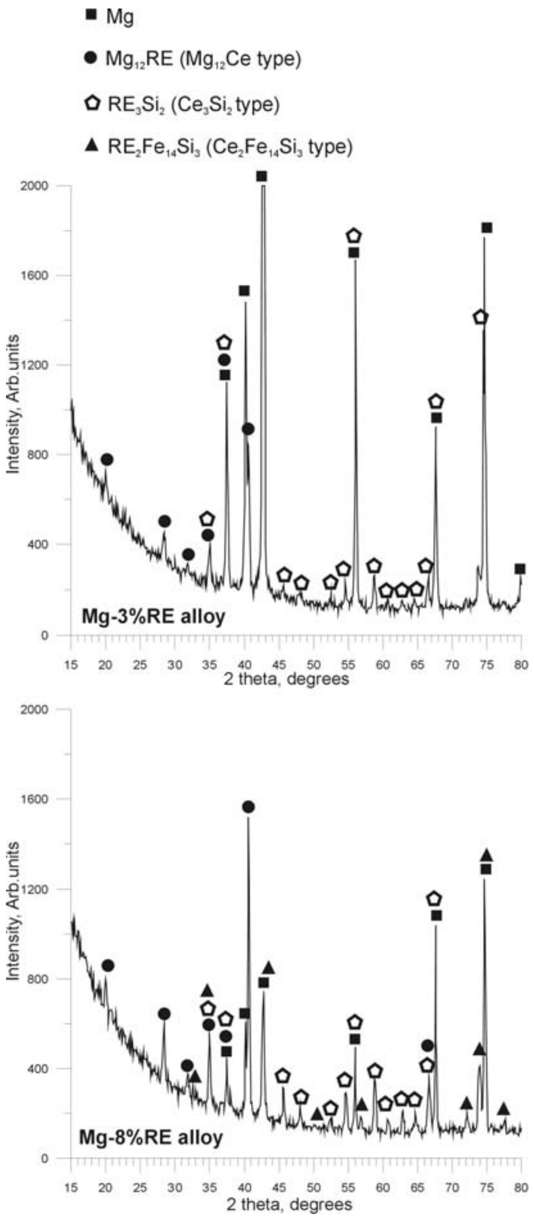

Fig. 6. XRD diffraction patterns of as-cast Mg–3%RE and Mg–8%RE alloys

4. Summary

Addition of 3 or 8 wt.% cerium – rich mish metal to magnesium casuses the formation of dendritic microstructure consisting of primary α phase and α + $Mg_{12}RE$ phase divorced eutectic. Impurities in magnesium alloys very often form during the fabrication process. In the investigated alloys, the RE_3Si_2 and $RE_2Fe_{14}Si_3$ type intermetallic compounds with various morphology (needle-like, square-like) were revealed. These phases formed from contamination of alloys with silicon and iron, but some parts of them may act as heterogeneous nucleation sits for magnesium dendrites.

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