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Microstructure and Mechanical Properties of Mg-Y-Sm-Ca Alloys

Qing Zhang [a], Quan-an Li, Jun Chen, Xing-yuan Zhang

School of Materials Science and Engineering, Henan University of Science and Technology, Luoyang 471023, China

[a] email: foxzq@126.com

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Abstract: The microstructure and mechanical properties of as-cast Mg-5Y-(2, 3, 4)Sm-0.8Ca (wt.%) alloys have been investigated. The results show that the microstructure of as-cast alloys consists of α-Mg matrix, $Mg_{24}Y_5$, $Mg_{41}Sm_5$ and Mg_2Ca. With the increase of Sm addition, the tensile strength increases at first, and then decreases. Mg-5Y-3Sm-0.8Ca alloy has the highest strength and can be a basis for developing light structural materials.

Introduction

Magnesium alloys-the lightest metallic structural materials and "the 21st green engineering materials"-have been widely used in the fields of automobile manufacturing and electronic industry due to their low density, high specific strength/stiffness, excellent damping effect and good recycling potential [1-5]. However, the heat resistance of traditional magnesium alloys is unsatisfactory, which has been the main factor of limiting the further wider application of magnesium alloys. It is necessary for magnesium alloy researchers to find a basis for developing light structural materials.

Alloying, especially rare earth alloying, is applied to improve the properties of magnesium alloys [6]. Y (yttrium) is one of the important rare earth elements, and has a high solid solubility in Mg. The addition of Y can enhance the strength of magnesium alloys. It is believed that Y is the most effective rare earth element to improve the properties of magnesium alloys at high temperatures [7]. Moreover, simultaneous addition of yttrium and samarium (Sm) has been found to be significantly effective to increase the strength properties of magnesium alloys by D.Q. Li (Li Daquan) et al. [8-10].

In this work, rare earth elements Y and Sm and alkaline earth element Ca are introduced into pure magnesium and the microstructure and mechanical properties of as-cast Mg-Y-Sm-Ca alloy are studied. It is hoped to provide a basis for the development of new type magnesium alloys.

Experimental

The compositions of tested Mg-Y-Sm-Ca alloy were designed as Mg-5Y-(2, 3, 4)Sm-0.8Ca (wt.%). Pure metallic magnesium (99.95 wt.%) and Mg-25 wt.% Y, Mg-25 wt.% Sm and Mg-25 wt.% Ca master alloys were used as raw materials.

All the raw materials were baked at 200℃ before the melting started. The alloys were melted in an induction furnace with an Al_2O_3 crucible under the protection gas of 99 vol.% CO_2 and 1 vol.% SF_6. The melt was heated to 750℃, and was poured into a metallic mold. The specimens were obtained after machining.

The tensile tests were carried out at a strain rate of 1mm/min in an AG-I 250kN precision universal material test machine at room temperature. The phase analysis was performed by D8 Advance X-ray diffract meter (XRD). The microstructure observation was made by Olympus optical microscopy (OM).

Results

The XRD patterns of as-cast Mg-Y-Sm-Ca alloys are shown in Fig. 1. The results show that the microstructure of as-cast Mg-Y-Sm-Ca alloys consists of α-Mg matrix, $Mg_{24}Y_5$, $Mg_{41}Sm_5$ and Mg_2Ca.

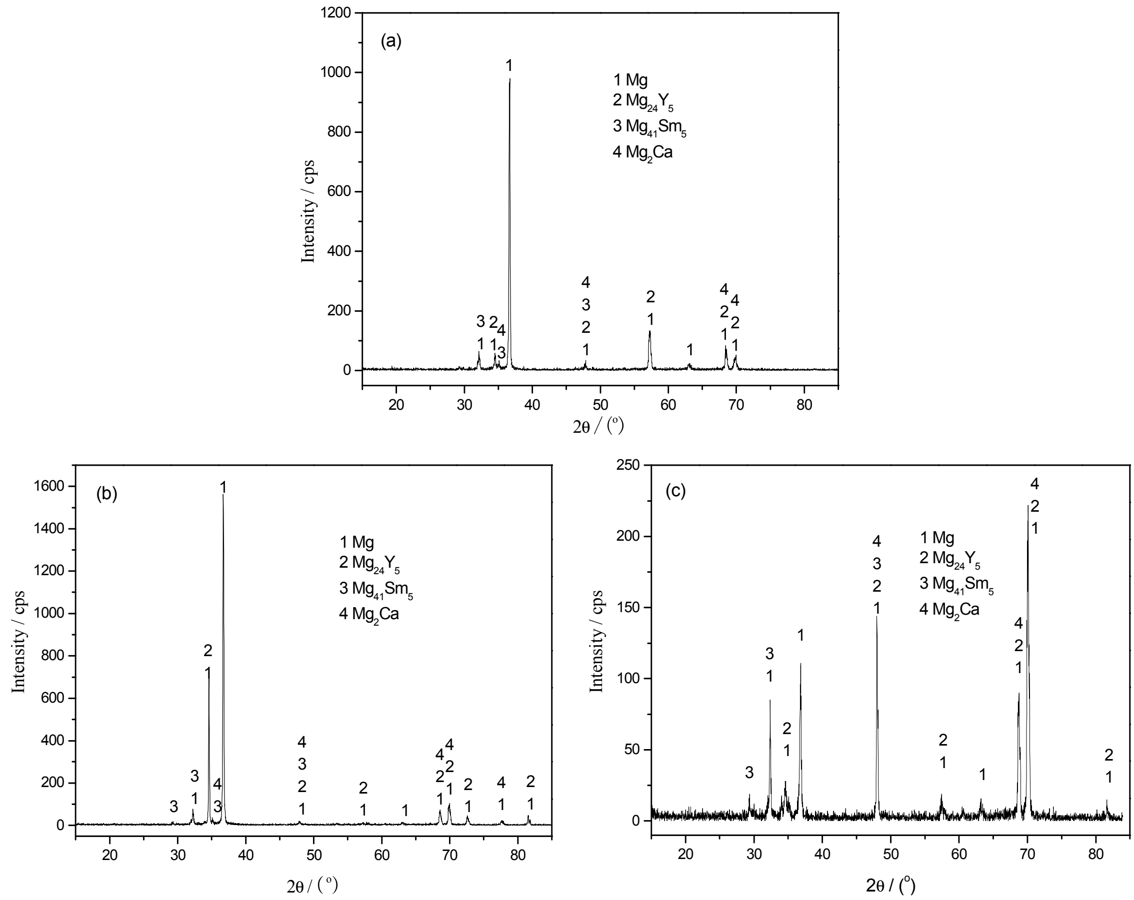

Fig. 1 XRD patterns of as-cast Mg-Y-Sm-Ca alloys

(a) Mg-5Y-2Sm-0.8Ca (b) Mg-5Y-3Sm-0.8Ca (c) Mg-5Y-4Sm-0.8Ca

The microstructure of as-cast Mg-Y-Sm-Ca alloys is shown in Fig. 2. It can be seen that the microstructure of the alloys consists of white matrix and grey precipitates. Sm addition has an important effect on the microstructure of Mg-Y-Sm-Ca alloys. With the increase of Sm addition, the grain size and the precipitate morphology have obvious changes.

It can be seen from Fig. 2a that there are some coarse precipitates in Mg matrix of Mg-5Y-2Sm-0.8Ca alloy. The microstructure of Mg-5Y-3Sm-0.8Ca alloy is shown in Fig. 2b. It can be seen that the microstructure is similar to that of Mg-5Y-2Sm-0.8Ca alloy shown in Fig. 2a, but the amount of precipitate phase is larger, and the grain size is finer. It can enhance the mechanical properties of the alloy with 3%Sm. When the content of Sm addition is up to 4%, the precipitate phase is much more in amount and the grain size is coarser (see Fig. 2c). It may damage the mechanical properties of the alloy with 4%Sm.

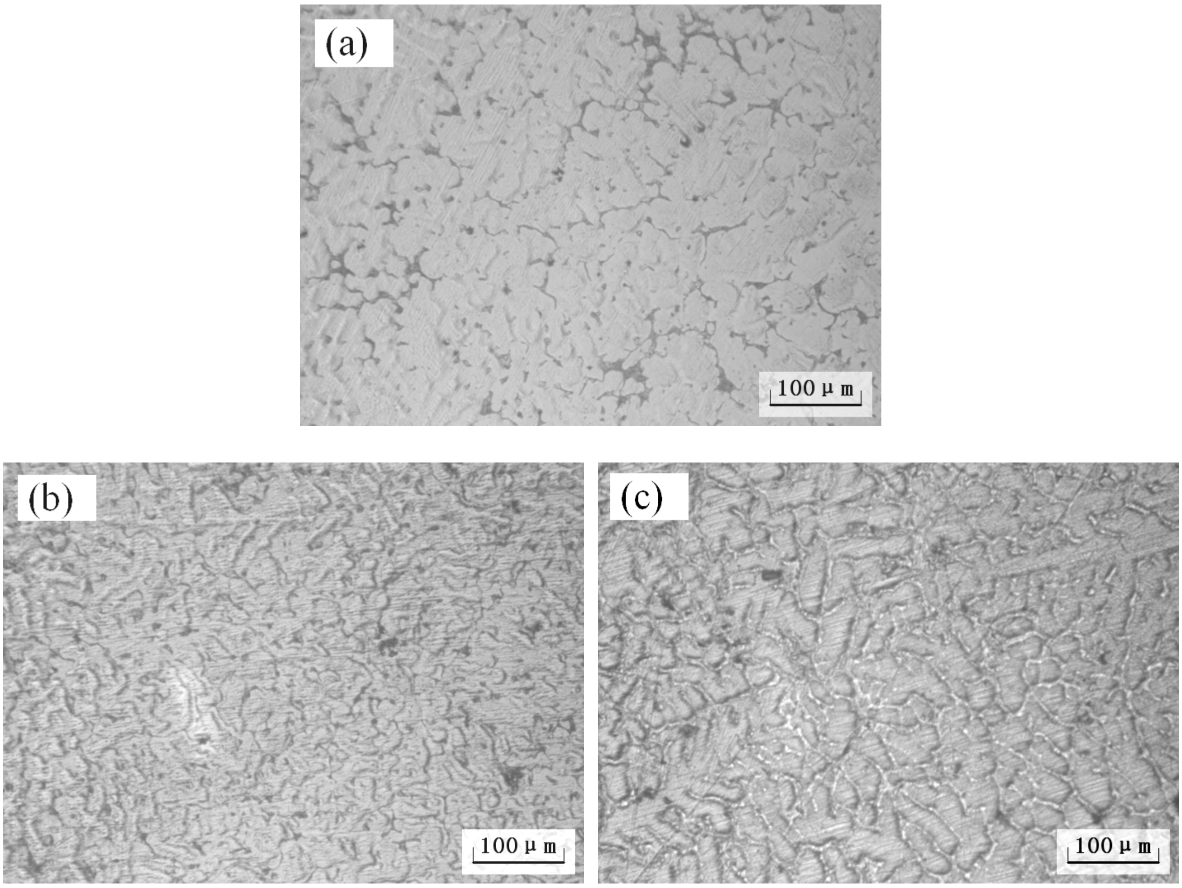

Fig. 2 Microstructure of as-cast Mg-Y-Sm-Ca alloys
(a) Mg-5Y-2Sm-0.8Ca (b) Mg-5Y-3Sm-0.8Ca (c) Mg-5Y-4Sm-0.8Ca

The mechanical properties of as-cast Mg-Y-Sm-Ca alloys are shown in Table 1. It can be seen that, with the increase of Sm content, the tensile strength of the alloy at room temperature increases at first, and then decrease. When the content of Sm addition is 2%, the tensile strength is not high, 192MPa. When the content of Sm addition is 3%, the tensile strength is up to the maximum, 208MPa. Compared with that of Mg-5Y-2Sm-0.8Ca alloy, the strength of Mg-5Y-3Sm-0.8Ca alloy is enhanced by 16MPa. When the content of Sm addition is up to 4%, the tensile strength of the alloy decreases, which is consistent with the result of microstructure analysis. It also can be seen that the change of the elongation is similar to that of the tensile strength.

Among these alloys, Mg-5Y-3Sm-0.8Ca alloy has the highest strength. After proper alloying and/or heat treatment, the strength of the alloy will be further enhanced. It can be a basis for the development of light structural materials.

Table 1 Mechanical properties of as-cast Mg-Y-Sm-Ca alloys

Alloy	Tensile strength/MPa	Elongation/%
Mg-5Y-2Sm-0.8Ca	192	3.1
Mg-5Y-3Sm-0.8Ca	208	3.7
Mg-5Y-4Sm-0.8Ca	196	3.3

Rare earth element Sm has a high solubility in Mg. It can cause the formation of $Mg_{41}Sm_5$. The main reasons for Sm to improve the mechanical properties of Mg-Y-Sm-Ca alloys are the function of grain refinement strengthening, solution strengthening and secondary phase strengthening.

It follows that rare earth element Sm plays an important role in strengthening Mg-Y-Sm-Ca alloys. When the content of Sm addition is suitable, the mechanical properties of Mg-Y-Sm-Ca alloy can be improved by the above three strengthening mechanisms. When the content of Sm addition is excessive, the comprehensive strengthening effects may be impaired and the mechanical properties of Mg-Y-Sm-Ca alloy may be weakened.

Conclusions

The microstructure of as-cast Mg-5Y-(2, 3, 4)Sm-0.8Ca alloys consists of α-Mg matrix, $Mg_{24}Y_5$, $Mg_{41}Sm_5$ and Mg_2Ca. Among these alloys, Mg-5Y-3Sm-0.8Ca alloy has the highest strength and can be a basis for developing light structural materials.

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