ARCHIVES
of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 15
Special Issue
3/2015

73 – 76

14/3

Possibilities of Fabricating Mg-Al-RE Cast Magnesium Matrix Composites Reinforced with Ti Particles

E. Przełożyńska, K.N. Braszczyńska-Malik*
Czestochowa University of Technology, Institute of Materials Engineering,
Al. Armii Krajowej 19, 42-200 Czestochowa, Poland
* Corresponding author. E-mail address: kacha@wip.pcz.pl

Received: 29.05.2015; accepted in revised form: 20.07.2015

Abstract

The results of microstructure investigations of an experimental magnesium matrix composite reinforced with Ti particles are presented. The experimental Mg-5Al-5RE magnesium alloy was used as the matrix alloy. The examined composite was reinforced with 30 wt% titanium spherical particles. The investigated material was obtained by the stir-casting method. The microstructure of the fabricated composite was characterized by a uniform arrangement of the Ti particles within the magnesium matrix. No new phases (created due to reaction between the matrix and Ti particles) were revealed by XRD techniques.

Keywords: Composite, Mg-Al-Mn alloy, Rare earth elements, Ti particles, Microstructure

1. Introduction

Magnesium alloys because of their low density, good specific strength and stiffness, exceptional dimensional stability and high damping capacity are widely used mainly in the automotive and aerospace industries. Most commercial magnesium alloys are based on the Mg-Al system [1-3].

However, commercial cast magnesium alloys (AZ and AM series) have poor creep resistance above 125^{o}C which makes them inadequate for major powertrain applications [4]. An a effective way to improve the mechanical properties of Mg alloys at elevated temperatures is to add alloying elements like Sr, Sb, Ca, Bi and rare earth (RE) metals which cause the formation of thermally stable precipitates along the grain boundaries [4, 5]. Mg-Al-RE alloys deserve special consideration and are the subject of many studies [6-8]. For example, the AE44 alloy (Mg-4Al-4RE) developed by Hydro Magnesium has good creep resistance up to 200^{o}C [6].

Magnesium matrix composites are materials that are constantly being developed [9]. Recently, an Mg-RE base metal matrix composite with SiC_p fabricated by powder metallurgy technique was also examined [10]. Ceramic particles are the most widely studied reinforcing materials for Mg-based composites but metallic/intermetallic particles are also investigated [11-15].

The paper focuses on the microstructure of an experimental Mg-5Al-5RE magnesium alloy matrix composite with Ti particles fabricated by the stir-casting method.

2. Experimental procedure

The commercial AM50 magnesium alloy (fabricated by Hydro Magnesium Ltd.) with the nominal composition given in

Table 1 was chosen as the base alloy. Rare earth elements in the form of cerium rich mish metal were used as the addition. The chemical composition of the mish metal is listed in Table 2. An experimental alloy with 5 wt% rare earth elements was made by the casting method involving introducing the RE alloying element into the molten AM50 alloy. During the melting process a protective argon atmosphere was employed.

Table 1.
Chemical composition of AM50 alloy according to standard ASTM B93-94

Chemical composition [wt.%]*)						
Alloy	**Al**	**Mn**	**Zn**	**Si**	**Fe**	**Cu**
AM50	4.5÷5.3	0.28÷0.5	max 0.02	max 0.05	max 0.004	max 0.008
*) Mg rest						

Table 2.
Chemical composition of mish metal (according to the attestation)

Chemical composition [wt.%]*)						
	Ce	**La**	**Nd**	**Pr**	**Fe**	**Mg**
mish metal	54.80	23.80	16.00	5.40	0.16	0.19

Titanium powder in the form of spherical particles (with the nominal composition given in Table 3) was chosen as the reinforcement for the composite. The fraction of the Ti particles was under 50 μm. The experimental composite was obtained by introducing 30 wt% titanium particles to the mechanical mixing of the molten Mg-5Al-5RE magnesium alloy fabricated earlier under a protective atmosphere. The prepared composite suspension was gravity cast into a metal mould.

The standard metallographic technique of grinding and polishing followed by etching in a solution of 1% nitric acid in alcohol was used for sample preparation. The microstructure of the fabricated material was examined using a light microscope (LM – Olympus UC30). Phase constitutions of the investigated composite were analyzed by X-ray diffraction (XRD) using a Brucker D8 Advance diffractometer. $Cu_{K\alpha}$ X-ray radiation was used.

Table 3.
Chemical composition of Ti particles according to ASTM B-348, grade 1

Chemical composition [wt.%]*)					
C	**O**	**N**	**H**	**Fe**	**Others each**
0.02	0.10÷0.18	0.02	0.01	0.05÷0.20	max 0.1
*) Ti rest					

3. Results

Figure 1a shows a typical microstructure of the AM50 alloy, which is composed of an α solid solution (Mg), divorced eutectic α+γ (where γ is the $Mg_{17}Al_{12}$ phase) and aluminium-manganese compounds. The microstructure of the fabricated experimental Mg-5Al-5RE alloy (AM50 with addition of 5 wt% rare earth elements) is shown in Fig. 1b and c. The addition of rare earth elements caused the formation of $Al_{11}RE_3$ and Al_2RE phases with a needle-like and polygonal morphology, respectively. The presence of a ternary intermetallic compound ($Al_{10}RE_3Mn_7$) was also observed due to the small mass fraction of manganese in the alloy composition.

(a) (b) (c)

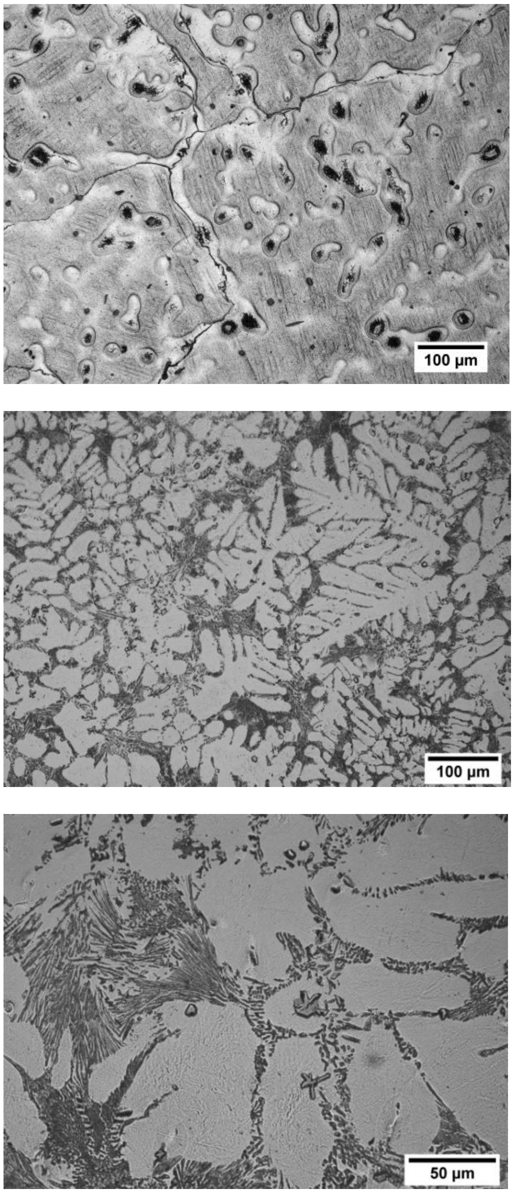

Fig. 1. Microstructure of as-cast AM50 (a) and Mg-5Al-5RE (b, c) alloys, LM

Figure 2 shows the as-cast microstructure of the fabricated Mg-5Al-5RE-Ti_p composite which is characterized by uniform distribution of the titanium particles within the magnesium matrix. No consequences of floating or sedimentation of the reinforcement were observed. Furthermore, particle clusters were not revealed either. Uniform distribution of the reinforcement is the result of good wettability of Ti particles by the molten matrix alloy.

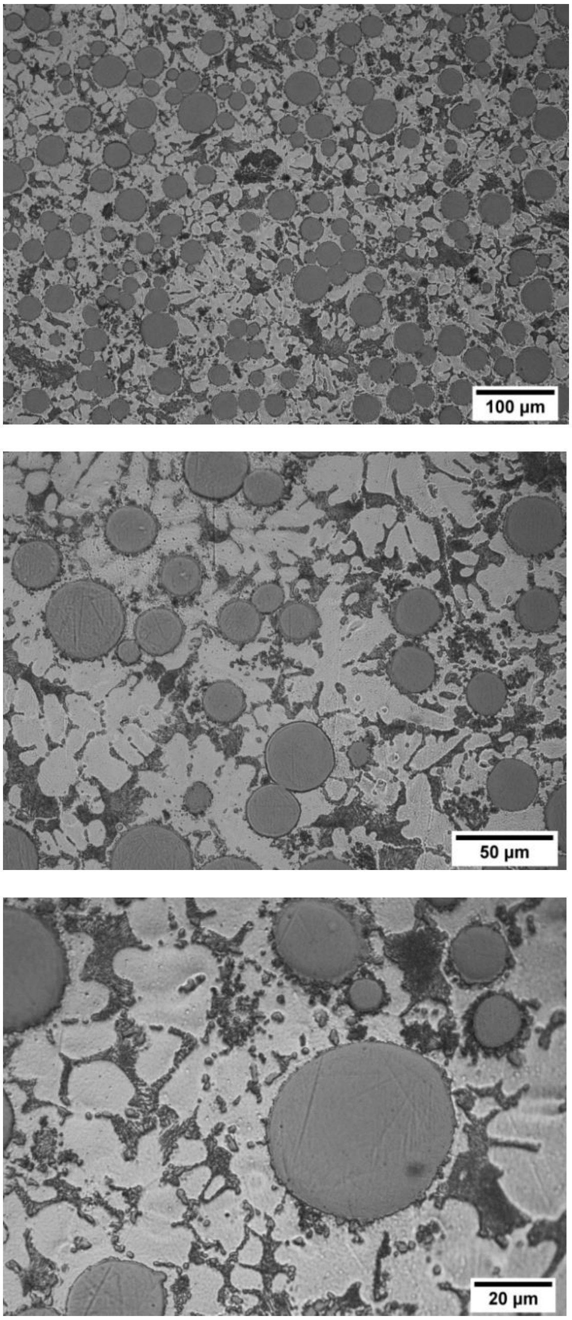

Fig. 2. Microstructure of Mg-5Al-5RE–Ti_p composite, LM

In order to identify the existing phases in the fabricated composite, XRD analysis was performed. Fig. 3 shows a representative X-ray diffraction pattern of the Mg-5Al-5RE-Ti_p material. The diffraction lines were indexed as arising from six different phases. The examined composite is mainly composed of an α (Mg) solid solution, ternary intermetallic compound $Al_{10}Re_2Mn_7$ (because of the small amount of manganese), $Al_{11}RE_3$ and A_2RE phases and Ti_α phase (which was added as reinforcement). No new phases which could be created due to the reaction between the Mg-5Al-5RE matrix alloy and Ti particles were revealed. On the other hand, the XRD analysis also revealed a small reflex from MgO which could be a result of oxidation of the examined sample.

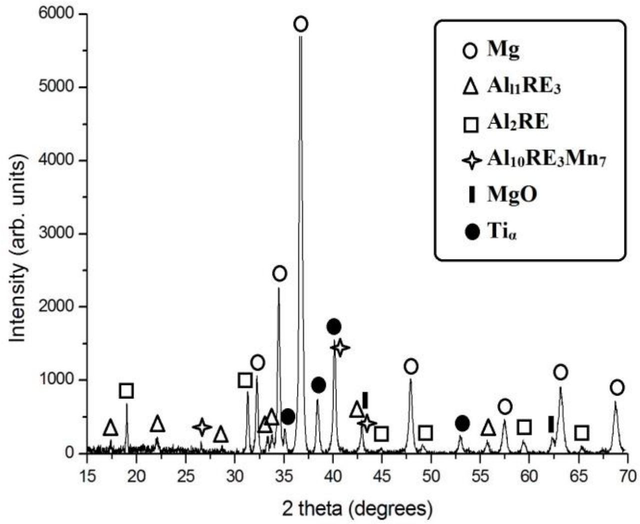

Fig. 3. X-ray diffraction pattern of as-cast Mg-5Al-5RE-Ti_p composite

4. Summary

The examined Mg-5Al-5RE magnesium matrix composite with titanium particles fabricated by the stir-casting method is characterized by uniform distribution of the reinforcement within the matrix. According to the presented results of the investigation, no new phases (created due to reaction between the Mg-5Al-5RE matrix and Ti particles) were revealed by the microstructure observations and XRD techniques.

References

[1] Luo, A.A. (2013). Applications: aerospace, automotive and other structural applications of magnesium. *Fundamentals of magnesium alloy metallurgy* (266÷316). UK: Woodhead Publishing Limited.

[2] Kulekci, M.K. (2008). Magnesium and its alloys applications in automotive industry. *The International Journal of Advanced Manufacturing Technology 39*, 851÷865.

[3] Stjohn, D.H., Easton, M.A., Qian, M. & Taylor, J.A. (2012). Grain refinement of magnesium alloys: a review of recent research, theoretical development and their application. *Metallurgical and Materials Transactions 44A*, 2935÷2950.

[4] Yang, Z., Li, J.P., Zhang, J.X., Lorimer, G.W. & Robson, J. (2008) Review on research and development of magnesium alloys. *Acta Metallurgica Sinica 21*, 313÷328.

[5] Ali, Y., Qiu, D., Jiang, B., Pan, F. & Zhang, M.-X. (2015). Current research progress in grain refinement of cast magnesium alloys: A review article. *Journal of Alloys and Compounds 619*, 639÷651.

[6] Rzychoń, T., Kiełbus, A. & Lityńska-Dobrzyńska, L. (2013). Microstructure, microstructural stability and mechanical properties of sand-cast Mg-4Al-4RE alloy. *Materials Characterization 83*, 21÷34.

[7] Żydek, A., Kamieniak, J. & Braszczyńska-Malik, K.N. (2010). The effect of rare earth elements on the microstructure of as-cast AM50 alloy. *Archives of Foundry Engineering 10*, 147÷150.

[8] Zhang, J., Liu, S., Leng, Z., Zhanf, M., Meng, J. & Wu, R. (2011). Microstructure and mechanical properties of heat-resistant HPDC Mg-4Al-based alloys containing cheap misch metal. *Materials Science and Engineering A. 528*, 2670÷2677.

[9] Dieringa, H. (2013). Applications: magnesium-based metal matrix composites (MMCs). *Fundamentals of magnesium alloy metallurgy* (pp. 317÷341). UK: Woodhead Publishing Limited.

[10] Cabibbo, M. & Spigarelli, S. (2011). A TEM quantitative evaluation of strengthening in an Mg-RE alloy reinforced with SiC, *Materials Characterization 62*, 959÷969.

[11] Ye, H.Z. & Liu, X.Y. (2004), Review of recent studies in magnesium matrix composites. *Journal of Materials Science 39*, 6153÷6171.

[12] Kondoh, K., Kawakami, M., Imai, H., Umeda, J. & Fuji, H. (2010). Wettability of pure Ti by molten pure Mg droplets. *Acta Materialia 58*, 606÷614.

[13] Hassan, S.F. & Gupta, M. (2002). Development of ductile magnesium composite materials using titanium renforcement. *Journal of Alloys and Compounds 345*, 246÷251.

[14] Braszczyńska-Malik, K.N. & Przełożyńska, E. (2014). Metal-metal cast composites. *Archives of Foundry Engineering 14*, 110÷113

[15] Braszczyńska-Malik, K.N. & Przełożyńska, E. (2014). Microstructure of AZ91-Ti6Al4V metal-metal composite in as-cast conditions and after heat treatment. *Composites Theory and Practice 14*, 224÷228.