Materials Science & Engineering A 675 (2016) 55–64

Contents lists available at ScienceDirect

Materials Science & Engineering A

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

Fabrication of high strength α, α+β, β phase containing Mg-Li alloys with 0.2%Y by extruding and annealing process

Yan Tang, Weitao Jia, Xuan Liu, Qichi Le*, Yulei Zhang

Key Lab of Electromagnetic Processing of Materials, Ministry of Education, Northeastern University, Shenyang 110819, China

ARTICLE INFO

Article history:
Received 18 June 2016
Received in revised form
1 August 2016
Accepted 2 August 2016
Available online 4 August 2016

Keywords:
Microstructural evolution
Precipitation strengthening
Recrystallization
Annealing
Strength

ABSTRACT

The microstructural evolution and a precipitation strengthening behavior of Mg-xLi-3Al-2Zn-0.2Y (x=5, 8, 11) by extruding and annealing process were investigated. Results show that when annealing at 300 °C for 6 h and 12 h and 24 h, the $MgAlLi_2$ phase decomposes and vanishes from the matrices, meanwhile, recrystallization behavior of α and β grains can be observed. After annealing at 250 °C, in the Mg-8Li-3Al-2Zn-0.2Y and Mg-11Li-3Al-2Zn-0.2Y, a great deal of intermetallic compounds (1.8–2.5 μm) extensively precipitate from β phase. In contrast, no evident precipitation behavior happens in the Mg-5Li-3Al-2Zn-0.2Y. The large number of dispersive precipitates in β phase significantly enhance the strength of the alloys.

1. Introduction

Mg-Li alloys are the lightest metallic structural materials [1], there are many advantages such as outstanding formability, high specific strength and outstanding damping ability [2]. Therefore, Mg-Li alloys have been comprehensively drawn attention in the fields of weapon, aerospace, automobile and portable equipment and so on [3]. Addition of Li into Mg alloys can decrease the c/a ratio to activate much more slip systems, meanwhile, the crystal structure will be transformed from hexagonal close packed (HCP) to body-centered cubic (BCC) [4]. But Mg-Li alloys have the relatively low strength which is a very important problem to be solved at present. Many researchers have adopted some methods such as alloying strengthening [4–14], ageing strengthening [15] and solution strengthening [16] to handle this problem. Furthermore, these measures have accomplished some positive strengthening effects on mechanical properties [4–21]. The solid solubility of aluminum and zinc both are relatively high in the Mg alloys and they can enhance the strength of the alloys by solution strengthening and precipitation strengthening [5–22]. In the ageing and solution strengthening, the temperature generally controlled by previous researchers is below 200 °C and 330 °C above and there are few reports about precipitation strengthening in β phase through annealing process. Consequently, high strength Mg-Li alloys with 0.2%Y fabricated by extruding and annealing process were investigated.

2. Experimental

Mg-xLi-3Al-2Zn-0.2Y (x=5, 8, 11) alloys were fabricated in a resistance furnace. Materials used in the experiment were commercially pure magnesium ingot, pure aluminum ingot, pure zinc ingot, Mg-25% Y master alloy ingot. In the melting period, a mixture flux (75% LiCl+25% LiF) was used to keep the melt away from the air. After being melted, the melt was poured into the steel mold to obtain as-cast specimens at the atmosphere of SF_6 gas.

As-cast specimens were homogenized at 200 °C for 8 h, then machined into ingots with the size of ϕ 50 mm × 100 mm. Finally, machined ingots were extruded into rods at the temperature of 200 °C, extrusion ratio is 17:1. Extruded rods were cut into small specimens and tensile specimens for annealing treatment whose parameter is 200 °C for 6 h and 12 h and 24 h, 250 °C for 6 h and 12 h and 24 h, 300 °C for 6 h and 12 h and 24 h. At last, annealed specimens were dipped into the water for quenching.

Chemical composition of the as-cast specimens were analyzed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) and the results are listed in Table 1. The microstructures and fracture morphologies were observed by optical microscope (OM) and scanning electron microscope (SEM) with energy dispersive X-ray spectroscope (EDS). Phase analysis was measured by X-ray diffraction (XRD). Tensile tests were conducted on a vertical tensile machine with the speed of 1 mm/s at room temperature.

* Corresponding author.
E-mail address: qichil@mail.neu.edu.cn (Q. Le).

http://dx.doi.org/10.1016/j.msea.2016.08.007
0921-5093/

Table 1
Chemical composition of the as-cast alloys.

Designed alloy	Composition (wt%)				
	Li	Al	Zn	Y	Mg
Mg-5Li-3Al-2Zn-0.2Y	5.11	3.10	2.05	0.217	bal.
Mg-8Li-3Al-2Zn-0.2Y	7.96	3.04	2.04	0.199	bal.
Mg-11Li-3Al-2Zn-0.2Y	10.75	3.12	1.98	0.202	bal.

3. Results and discussions

3.1. Microstructural observations

Fig. 1 demonstrates the XRD patterns of the as-cast Mg-xLi-3Al-2Zn-0.2Y (x=5, 8, 11), it indicates that the three alloys all consist of α-Mg, β-Li, Al_2Y, AlLi, $Mg_{17}Al_{12}$, $MgAlLi_2$, moreover, according to the peak altitude, Mg-5Li-3Al-2Zn-0.2Y is mainly composed of α phase (as shown in Fig. 1(a)), Mg-8Li-3Al-2Zn-0.2Y is mainly composed of α+β dual-phase (as shown in Fig. 1(b)), Mg-11Li-3Al-2Zn-0.2Y is mainly composed of β phase (as shown in Fig. 1(c)).

Fig. 2 manifests the microstructures of the three as-cast alloys. Mg-5Li-3Al-2Zn-0.2Y mainly consists of α-Mg (white snowflake shape) and β-Li (dark gray discontinuous network shape) and

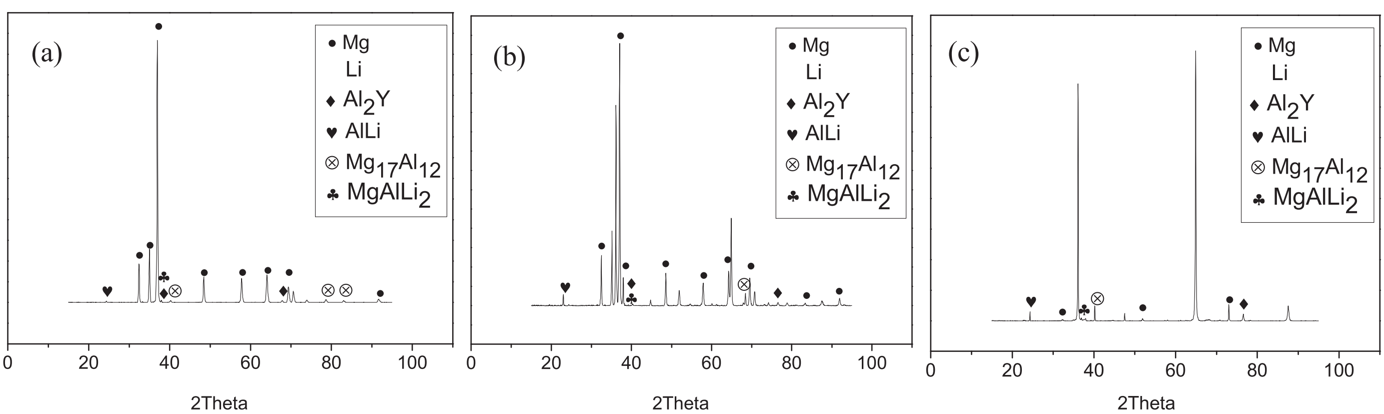

Fig. 1. XRD patterns of the as-cast alloys: (a) Mg-5Li-3Al-2Zn-0.2Y; (b) Mg-8Li-3Al-2Zn-0.2Y; (c) Mg-11Li-3Al-2Zn-0.2Y.

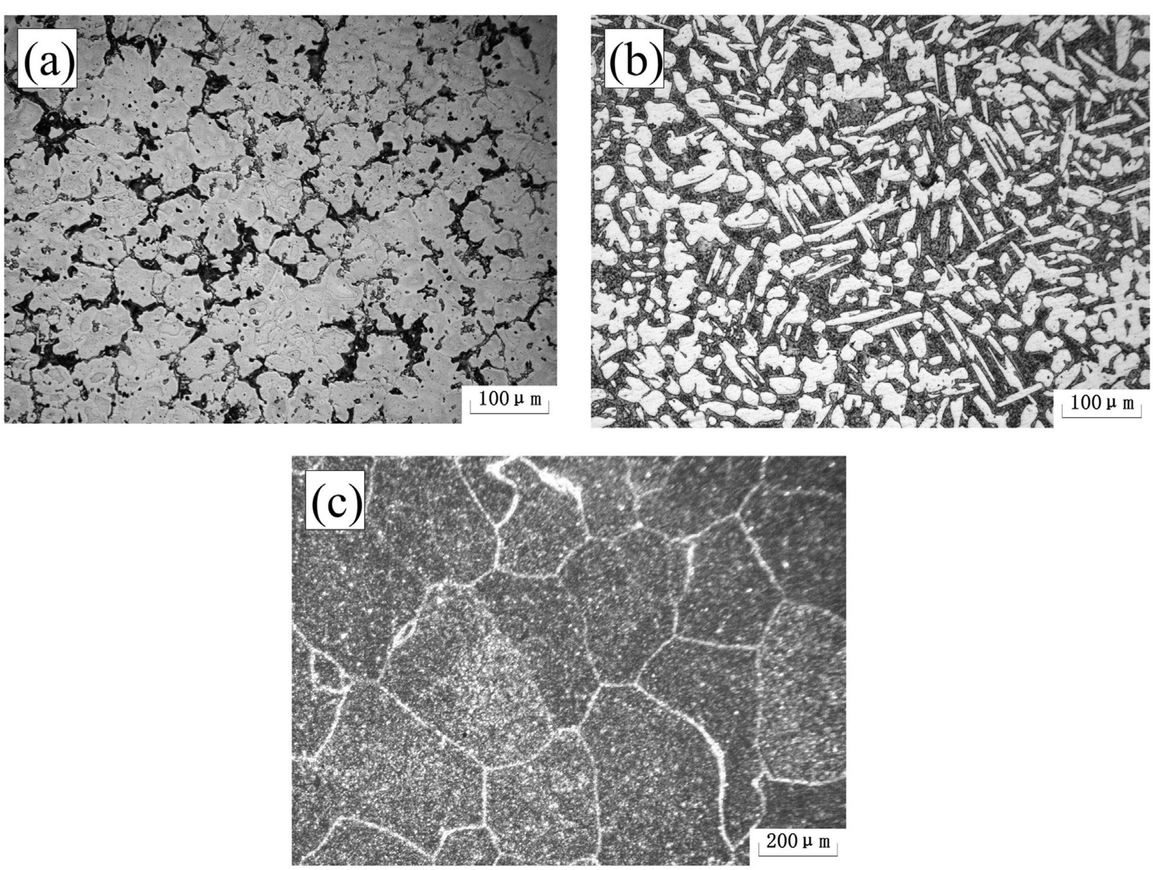

Fig. 2. Microstructures of the as-cast alloys: (a) Mg-5Li-3Al-2Zn-0.2Y; (b) Mg-8Li-3Al-2Zn-0.2Y; (c) Mg-11Li-3Al-2Zn-0.2Y.