Available online at www.sciencedirect.com
ScienceDirect
Trans. Nonferrous Met. Soc. China 23(2013) 1936−1941

Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Effect of Ce addition on microstructure of Mg−9Li alloy

Heng-mei YIN[1,2], Bin JIANG[1,2], Xiao-yong HUANG[1,2], Ying ZENG[1,2],
Qing-shan YANG[1,2], Ming-xing ZHANG[3], Fu-sheng PAN[1,2]

1. National Engineering Research Center for Magnesium Alloys, Chongqing University, Chongqing 400044, China;
2. College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China;
3. School of Mechanical and Mining Engineering, University of Queensland, St Lucia 4072, Australia

Received 15 April 2011; accepted 25 December 2012

Abstract: The as-cast and as-extruded Mg−9Li, Mg−9Li−0.3Ce alloys were respectively prepared through a simple alloying process and hot extrusion. The microstructures of these alloys were investigated by optical microscope (OM), scanning electron microscope (SEM), X-ray diffractometer (XRD) and energy dispersive spectrometer (EDS). The results indicate that Ce addition produces a strong grain refining effect in Mg−9Li alloy. The grain size of the as-extruded alloy reduces abruptly from 88.2 μm to 10.5 μm when the addition of Ce is 0.36%. $Mg_{12}Ce$ is verified and exists inside the grains or at the grain boundaries, thus possibly pins up grain boundaries and restrains the grain growth.

Key words: magnesium−lithium alloys; microstructure; grain refinement; intermetallic compound

1 Introduction

Mg−Li alloys are the lightest magnesium alloys [1] and have much better plasticity than the general Mg−Al or Mg−Zn alloys [2,3]. According to the Mg−Li phase diagram, with Li content between 5% and 11%, BCC-structured *β* phase of Li solid solution will co-exist with the HCP-structured *α* phase of Mg solid solution [4]. The *α* phase exhibits moderate strength [5−7]. The *β* phase is well known to exhibit good formability [8−10] but possesses relatively low strength and work hardening capacity [11,12]. Therefore, the strength of Mg−Li binary alloys is relatively low. Grain refinement can strengthen the alloy with the increase of strength and plasticity. Minor element addition [13], which is particularly suitable for mass production, is a simple and economical method to refine the microstructure. Compared with the addition of Nd, Ag [6,14] or Y [15] into Mg−Li alloys, Ce is a cheaper RE element and has shown strong potential to refine and strengthen Mg alloys [16−18]. Moreover, many researches [19−23] have indicated that Ce addition could not only refine the grains of Mg−Li alloys, but also strengthen both *α* phase and *β* phase of Mg−Li alloys through the formation of Mg−Ce or Al−Ce intermetallic compounds. Hence, in this work, Mg−9Li−0.3Ce alloy was prepared to examine the effect of Ce on the microstructure of as-cast and extruded Mg−9Li alloys.

2 Experimental

The materials used in this work were pure commercial magnesium and pure commercial lithium. Mg−20Ce master alloy was added into the alloys. In a typical procedure, pure magnesium and pure lithium blocks with or without addition of the master alloy were placed in steel crucibles (90 mm in diameter, 250 mm in height), respectively. Then, the crucibles were placed into an induction furnace, followed by pumping the furnace chamber to a vacuum state and inputting pure argon as a protective gas. Subsequently, the crucibles were heated to 700 °C until the charge was completely molten and then isothermally held for 10 min, followed by solidification and cooling of the melts with argon protection to minimize the oxidation. Finally, cast ingots (85 mm in diameter and 150 mm in height) were obtained. The compositions of the as-cast alloys were

Foundation item: Project (2007CB613706) supported by the National Basic Research Program of China; Project (2009AA03Z507) supported by the National High-tech Program of China; Projects (2010CSTC-HDLS, CSTC2010AA4048) supported by Chongqing Science and Technology Commission, China
Corresponding author: Heng-mei YIN; Tel: +86-18012680862; E-mail: yinhengmei1986@gmail.com
DOI: 10.1016/S1003-6326(13)62680-1

measured by inductively coupled plasma atomic emission spectroscopy (ICP-AES). The designed compositions and measured results of all the alloys prepared in the experiment are shown in Table 1.

Table 1 Chemical composition of experimental alloys (mass fraction, %)

Alloy No.	Nominal composition	Chemical composition
1	Mg−9Li	Mg−8.61Li
2	Mg−9Li−0.3Ce	Mg−9Li−0.3Ce

The extrusion was carried out at 250 °C and the extrusion ratio was 27. Before extrusion, the cast ingot was heat treated at 250 °C for 3 h. The Mg−9Li−0.3Ce bars with a diameter of 16 mm were obtained. Here, Mg−9Li alloy, as a reference sample, was prepared and extruded using the same procedure.

The samples used for microstructure observation were cut from the cast ingot or the as-extruded bar at the same position. Microstructure was observed by optical microscopy and scanning electron microscopy (SEM, TESCAN VEGA). Before observation, the specimens were polished and etched with an 4.0% etchant (volume fraction). The grain size was measured by the linear intercept method at the centre of transverse sections. The phase in the alloys was identified by Rigaku D/max 2500PC using Cu K_α radiation (λ=1.5418 Å) operating at 4 (°)/min and 10°−90° of 2θ.

3 Results and discussion

3.1 Grain size of Mg−9Li−0.3Ce alloy

Figures 1(a) and (b) show the optical microstructures of as-cast Mg−9Li alloys without or with Ce addition. The gray β phase and white α phase is observed in all samples. Notable grain refinement occurs with the addition of 0.36%Ce, which reduces the size of the α phase greatly so that it could not be distinguished from Fig. 1(b). The microstructures of the as-extruded Mg−9Li alloys without or with Ce addition are presented in Figs. 1(c) and (d). Equiaxed grains are observed. The grain size was abruptly reduced from 88.2 to 10.5 μm when the addition of Ce was 0.36%. It can be concluded

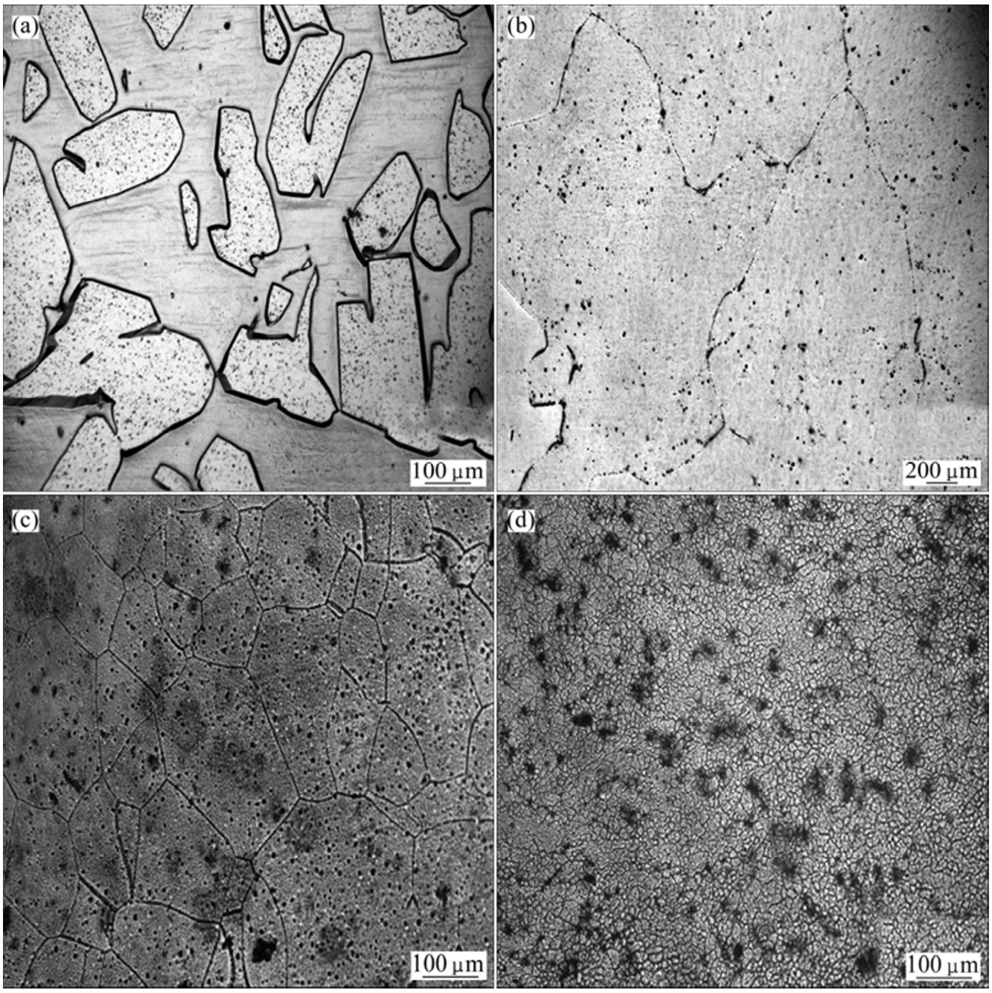

Fig. 1 Optical microstructures of alloys: (a) As-cast Mg−9Li alloy; (b) As-cast Mg−9Li−0.3Ce alloy; (c) As-extruded Mg−9Li alloy; (d) As-extruded Mg−9Li−0.3Ce alloy