Materials Science and Engineering A 528 (2011) 1149–1153

Contents lists available at ScienceDirect

Materials Science and Engineering A

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

Microstructure and mechanical properties of ZA62 Mg alloy by equal-channel angular pressing

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ARTICLE INFO

Article history:
Received 29 July 2010
Received in revised form
26 September 2010
Accepted 29 September 2010

Keywords:
Equal-channel angular pressing (ECAP)
Magnesium alloys
Bimodal
Severe plastic deformation
Superplasticity

ABSTRACT

The Mg–6Zn–2Al alloy was processed by ECAP and microstructure and mechanical properties of the alloy before and after ECAP were studied. The results revealed that the microstructure of the ZA62 alloy was successfully refined after two-step ECAP (2 passes at 473 K and 2–8 passes at 423 K). The course bulk interphase of $Mg_{51}Zn_{20}$ was crushed into fine particles and mixed with fine matrix grains forming "stripes" in the microstructure after the second step of ECAP extrusion. A bimodal microstructure of small grains of the matrix with size of ~0.5 μm in the stripes and large grains of the matrix with size of ~2 μm out of stripes was observed in the microstructure of samples after 4–8 passes of ECAP extrusion at the second step. The mechanical properties of the alloy studied were significantly improved after ECAP and the highest yield strength and elongation at room temperature were obtained at the samples after 4 and 8 ECAP passes at the second step, respectively. Tensile tests carried out at temperature of 473 K to 573 K and strain rate of $1 \times 10^{-3}\ s^{-1}$ to $3 \times 10^{-2}\ s^{-1}$ revealed that the alloy after 8 ECAP passes at the second step showed superplasticity and the highest elongation and strain rate sensitivity (*m*-value) reached 520% and 0.45, respectively.

1. Introduction

As the lightest structural material, Mg alloys have attracted growing interests in industries for reducing weight of products. However, Mg alloys have a hexagonal crystal structure, which limits the number of active slip systems so that they show poor ductility. Previous investigations reveal that equal-channel angular pressing (ECAP) is very effective for grain refinement and the microstructure of various Mg alloys with grain size of sub-micrometer or nanometer scales were produced through multipass ECAP which exhibited high strength at room temperature and superplasticity at relatively low temperatures [1–4].

Previous investigations reported that the as-casted ZA series alloys based on Mg–(6–12 wt.%)Zn–(1–6 wt.%)Al showed high strength at room temperature and good creep properties at elevated temperatures [5] and exhibited potentials in applications for components of industrial products. In this paper, the ECAP was performed on the ZA62 alloy and the microstructure and mechanical properties of the alloy before and after ECAP were studied.

2. Experimental materials and procedures

The ZA62 alloy was prepared in a mild steel crucible under the protection of a mixed gas atmosphere of SF_6 and CO_2 by using commercial pure stock of Mg, Zn and Al. The melt was held at ~950 K for 30 min and then poured into a cylindrical iron mould with 60 mm in diameter. The compositions of the alloy prepared were inspected by inductively coupled plasma (ICP) and the result is given in Table 1. The billet was homogenized at 593 K for 50 h and the ECAP samples were cut from billets and machined into a size of 12 mm × 12 mm × 60 mm.

ECAP tests were conducted with a 3D rotary-die having an internal angle between two channels of $\Phi = 90^\circ$ and an external arc of curvature of $\psi = 0^\circ$ and via route B_A' [6]. Two-step ECAP was carried out at 473 K and 433 K under a pressing speed of 1 mm/s. A mixture of graphite and Vaseline was coated on the surfaces of both samples and channels of the die. The samples were held in the die at the selected temperature for 10 min prior to the first pass and then held at temperature again for 3 min prior to each subsequent pass.

Microstructure observations and characterization of the phases existing in the microstructure of the ZA62 alloys were conducted using optical microscopy (OM), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and X-ray diffraction (XRD), respectively. Specimens with gauge lengths of 4 mm and cross-sections of 2 mm × 3 mm for tensile tests were cut and machined from the samples after ECAP processing and its longitu-

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doi:10.1016/j.msea.2010.09.096

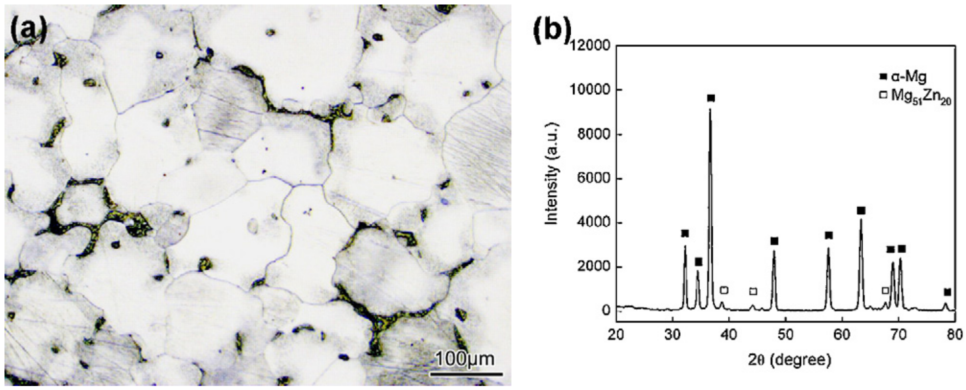

Fig. 1. optical micrograph (a) and XRD (b) pattern taken from of the ZA62 alloy before ECAP.

Table 1
Chemical compositions of the studied alloys inspected by the ICP method.

Alloys	Mg (wt.%)	Zn (wt.%)	Al (wt.%)
ZA62	Balance	6.39	2.04

dinal axis was parallel to the direction of ECPA presses. Tensile tests at elevated temperatures were performed at temperature of 473 K, 523 K and 573 K and strain rate of $1.0 \times 10^{-3}\ s^{-1}$ to $3.0 \times 10^{-2}\ s^{-1}$.

3. Experimental results

3.1. Microstructures

The as-cast samples of the alloy were annealed at 320 °C for 50 h to eliminate segregation which usually exists in as cast alloys. As shown in Fig. 1(a), an optical micrograph taken from the annealed alloy, the microstructure of the alloy after annealing consisted of the α-Mg matrix and a second phase which is mainly distributed at grain boundaries and the average grain size of the matrix phase is between 100 and 150 μm. The XRD pattern taken from the annealed sample is shown in Fig. 1(b), in which all the peaks was indexed as arising from the α-Mg matrix and an intermetallic compound $Mg_{51}Zn_{20}$. Therefore, the second phase shown in Fig. 1(a) can be identified as $Mg_{51}Zn_{20}$ (Fig. 2).

A two-step ECAP was performed on the annealed sample. For the first step, the sample was extruded two passes through the ECAP die at 473 K. At the second step, the 4 extruded samples after the first step ECAP processing was pressed through 2, 4, 6 and 8 passes, respectively, at temperature of 433 K. The microstructure of these four samples is shown in Fig. 1. After ECAP processing, the microstructure of the alloy was significantly changed. As shown in Fig. 1, the bulk second phase appearing in samples before ECAP was broken into small particles distributing along the direction of ECAP and arranged as a kind of "strips" in its microstructure. With increasing of ECAP passes, the grain size of the α-Mg matrix decreased. The average grain size of the samples after the first step of ECAP press was about 10 μm (Fig. 1a). It decreased to 5 μm

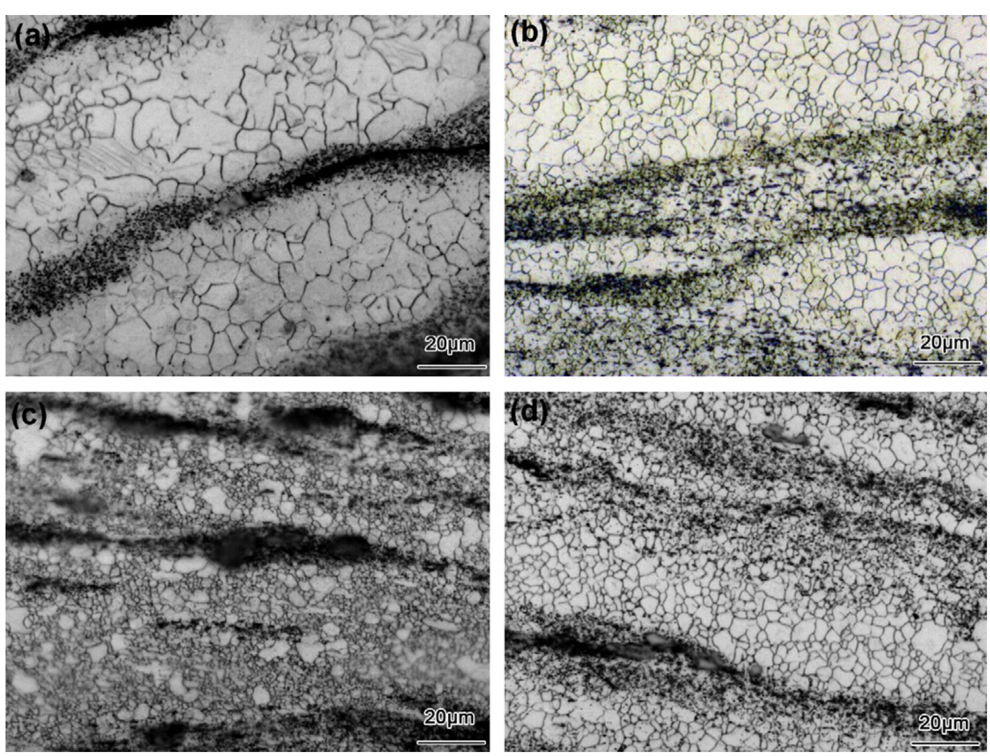

Fig. 2. Optical micrographs of the ZA62 Mg alloy, (a) after the first step ECAP, (b), (c), and (d) after 2, 4, 8 passes at the second step ECAP, respectively.