



Short communication

## Fabrication of a surface-porous magnesium–aluminium alloy

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### ARTICLE INFO

#### Article history:

Received 4 June 2014

Accepted 17 June 2014

Available online 23 June 2014

#### Keywords:

Mg alloy

Polarization

Acid corrosion

De-alloying

### ABSTRACT

In this investigation, an acetic acid (HAc) aqueous solution was found to be an effective electrolyte for an Mg–Al eutectic alloy de-alloying treatment. The corrosion morphologies showed that the Mg–Al eutectic alloy had an obvious selective corrosion character in the HAc solution. The pore formation mechanism was only governed by the  $\alpha$ -Mg dissolution. With prolonged corrosion time, the de-alloying rate was slowed down due to corrosive ion transfer becoming difficult at the corrosion interface.

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### 1. Introduction

Porous and foamed metallic materials have become an attractive research field both from a scientific viewpoint and the prospect of industrial applications because they exhibit many unusual combinations of physical and mechanical properties, such as impact energy absorption capacity, air and water permeability, high catalytic activity, and sensing capabilities [1–4]. The most promising technique used to prepare such porous metals is dealloying in aqueous solution. Dealloying is a selective corrosion phenomenon wherein the less noble component in an alloy is etched away selectively and the remaining component self-organizes into a three-dimensional porous structure [5–11]. Porous noble metals including Au [5,6], Pt [7], Pd [8], Cu [9,10] and Ag [11] have been prepared from binary alloy precursors of Au–Ag, Pt–Cu, Pd–Ni, Cu–Zn and Ag–Au, respectively. However, the formation of less noble porous metals by dealloying in aqueous solution has not been reported to date. The less noble metals are unstable in an aqueous solution and thus are oxidized immediately when they contact water.

Magnesium alloys are useful as lightweight, structural materials in applications that demand high specific properties [12]. The porous Mg alloys may be a better choice for satisfying these demands. However, there are challenges in producing porous Mg due to its flammability and reactivity with oxygen at elevated temperatures, particularly in the powdered form [13]. The fabrication of random porous Mg has been investigated by several workers via powder or chip sintering and low pressure casting [14–16]. Recently, porous Mg with periodic

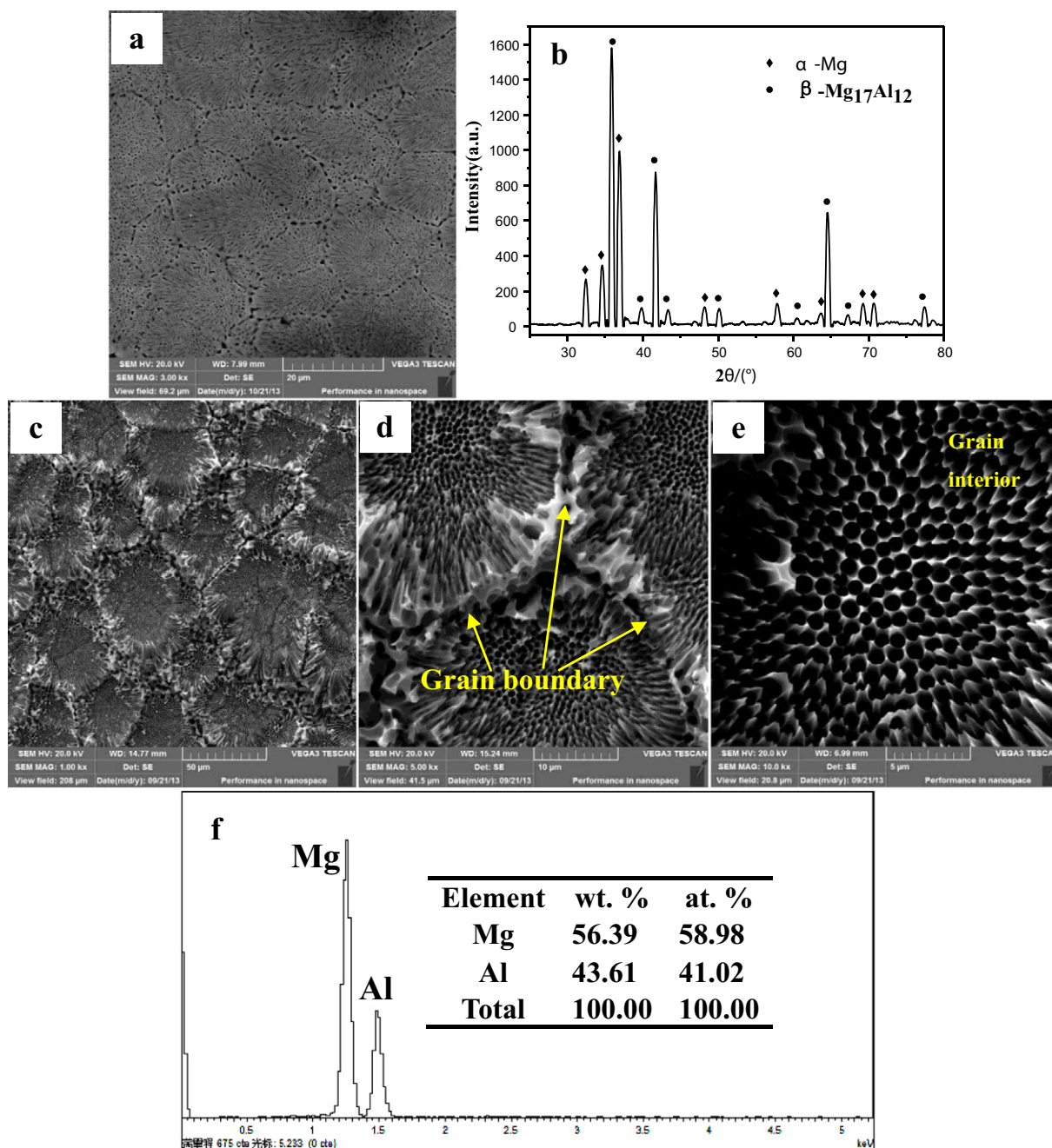
architectures has received more attention. For example, periodic porous Mg alloys can be directly fabricated using 3D printing technology or controlled porous spacer [17,18]. Obviously, these methods are complex and expensive. There is another porous material, surface porous material, which strength would not decrease compared with that of the material before the fabrication process of pores [19]. Moreover, these porous materials have many potential applications due to their merits like large specific surface area, excellent electromagnetic wave absorbability and well heat exchange capacity [20]. As a result, a low cost and relatively simple de-alloying method should be explored for active Mg-based alloys, which can be beneficial for the development of Mg alloys. In this investigation, a porous Mg–Al alloy was prepared using a de-alloying method, by which the fabrication of an Mg alloy with a porous surface layer is possible.

### 2. Experimental materials and methods

Pure Mg (99.95 wt.%) and pure Al (99.95 wt.%) were used as raw materials to prepare the Mg–Al eutectic alloy (70.5 at.% Mg and 29.5 at.% Al). The alloy was melted in a vacuum furnace with a graphite crucible. The crucible was put into the furnace and heated to 720 °C. The Mg and Al raw materials at the given ratio were then melted in the crucible under the protection of Ar gas. The key point was to control the homogeneity of the microstructure of the alloy that was fabricated. The casting temperature was 720 °C and the cooling rate was 30 °C/min to room temperature (25 °C) in the vacuum furnace. The fabrication process of single-phase Mg<sub>17</sub>Al<sub>12</sub> (SP Mg<sub>17</sub>Al<sub>12</sub>, 58.6 at.% Mg and 41.4 at.% Al) was similar to that of the Mg–Al eutectic alloy. The measurement of the corrosion potential difference between the two phases of the fabricated Mg–Al eutectic alloy would be helpful in determining the corrosion mechanism. Thus, pure Mg was used to represent the  $\alpha$ -Mg phase

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**Fig. 1.** (a) SEM morphology and (b) XRD pattern of an as-cast Mg–Al eutectic alloy; surface morphologies and EDS results of the Mg–Al eutectic alloy after de-alloying for 0.5 h in HAc aqueous solution: (c) sample surface morphologies, (d) grain boundary morphologies, (e) grain interior morphologies and (f) a typical EDS spectrum showing the composition of sample surface after being corroded for 0.5 h.

of the Mg–Al eutectic alloy. The SP  $Mg_{17}Al_{12}$  acted as the  $\beta$ - $Mg_{17}Al_{12}$  phase of the Mg–Al eutectic alloy.

The specimens for the corrosion test were 20 mm × 20 mm × 3 mm in size. All specimens were ground down to 2000 grit and then polished and cleaned with acetone and deionized water before the test. The pH of the HAc, HCl and  $H_2SO_4$  solutions is in the range of 1.0–1.1 and that of NaCl and  $NaNO_3$  solutions is 6.8–7.2. The corrosive solutions were changed every 30 min. A specimen was immersed for 0.5 h–1.5 h in the corrosive solution for de-alloying. After that, the de-alloyed specimen was cleaned using acetone and dried, the product being the surface-porous Mg–Al alloy.

Morphology observation and microstructure characterization of specimens were performed using a TESCAN VEGA3 field emission scanning electron microscope (SEM) with a resolution of 1 nm and an accelerating voltage from 15 to 30 kV, accompanied by an Oxford energy dispersive spectrometer (EDS). The Mg–Al eutectic composition was analyzed via a TD3500 X-ray diffraction (XRD) system. The electrochemical properties were analyzed using a PGSTAT30 electrochemical workstation. A three-electrode cell was employed in this test, where the sample was used as the working electrode, a saturated calomel electrode (SCE) was used as the reference electrode and a platinum sheet was used as the counter electrode. The scanning potential was in the

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