Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 184 (2017) 432 – 441

Procedia Engineering

www.elsevier.com/locate/procedia

Advances in Material & Processing Technologies Conference

Influence of Grain Refinement and Residual Stress on Corrosion Behavior of AZ31 Magnesium Alloy Processed by ECAP in RPMI-1640 Medium

Taito Hosaka[a], Shoichiro Yoshihara[a], Iman Amanina[a], Bryan J. MacDonald[b]

[a]*Department of mechanicalEngineering, University of Yamanashi, 4-3-11, Takeda, Kofu-city, Yamanashi, Japan*
[b]*School of Manufacturing and Mechanical Engineering, Dublin City University,* Dublin 9, *Ireland*

Abstract

Influence of grain refinement and residual stress on corrosion behaviour of AZ31 magnesium alloy processed by equal-channel angular pressing (ECAP) in vitro environment has been investigated. Microstructure of magnesium alloy has been obtained by ECAP process on the different temperature conditions. RPMI-1640 medium was adopted in the immersion test to investigate the effect of the carbonate buffer system and the organic compounds on the degradation behavior of AZ31 magnesium alloy. Additionally, the residual stress of ECAP processed (ECAPed) samples measurement by X-ray diffraction (XRD) was carried out. The results of XRD investigated that residual stress of the sample increases as the forming temperature decreases. The experimental results investigated that the organic compounds which are generated on the sample surface by corrosion reaction works as effective barrier to inhibit corrosion. Besides, the grain refinement and the crystal defects, which were induced by strain, promoted development and growth of pitting corrosion. However, the corrosion resistance of the ECAPed sample processed above the re-crystallization temperature was exceeded as-received sample. Furthermore, the corrosion resistance is expected to be improved by reducing defects via subsequent aging. This study is significant for applying the magnesium alloy in the biomedical implant material.

Peer review under responsibility of the organizing committee of the Advances in Materials & Processing Technologies Conference

Keywords: Corrosion, AZ31magnesium alloy, RPMI-1640 medium, Equal-channel angular pressing, Influence of Grain refinement, X-ray diffraction, residual stress

1. Introduction

Magnesium (Mg) is present in high concentrations in sea water and the eighth most abundant element on the earth. It has also excellent specific strength and low density, only two-thirds that of Aluminium. Thus, Mg and its

Peer review under responsibility of the organizing committee of the Advances in Materials & Processing Technologies Conference
doi:10.1016/j.proeng.2017.04.114

alloys could be adopted in many applications including computer parts, mobile phones, aerospace components and handheld tools [1]. Mg alloys are also potentially useful for bone implants and stent applications due to their low density, inherent biocompatibility, adequate mechanical properties and fracture toughness higher than those of ceramics [2]. In addition, the elastic modulus of Mg alloys (40–45GPa) is closer to human bones (10–40GPa) than other commonly used implant materials such as Titanium (Ti) (106GPa). Eventually, the stress-shielding phenomena caused by current metallic implants made of stainless steel or Ti alloy could be minimized [3].Another advantage of Mg in relation to other metallic implants is the degradability of Mg alloys which offers the possibility of repair and reconstruction of vascular compliance with minimum inflammatory response [4].

In recent years, the applications of bioabsorbable materials for medical implants have drastically increased [5]. Since Mg is an essential element in our body, it can be absorbed into the body without leaving any harm. Therefore, many studies have been focused on using Mg and its alloys for medical devices such as bioabsorbable stents [6]. Nowadays, the traditional permanent metallic materials for the stents are modern manufactured from stainless steel (316L), nitinol and cobalt-chromium alloys which have high corrosion resistance and remain as a permanent implant in the body. Thus, many limitations such as risk of chronic irritation caused by released toxic substances which might appear after long-term placement of the stents.

Mg is able to overcome many of these limitations since it could be absorbed into the body. For the patients with the coronary artery disease, the Mg stents could temporarily function as a scaffold for supporting the vascular stenosis. The disappearance of the Mg alloys stent is necessary after 6-12 months period [7]. Therefore, the structural integrity of the implanted stent has to be preserve until the surgical region has completely heal, hence the corrosion behaviour of Mg and its alloys have received attention in recent years. However, study on the degradation behaviour and mechanisms of Mg and its alloys in physiological environment such as inside the human body have not been elucidated.

The main factors affecting the corrosion performance of metallic materials as bioabsorbable stent include internal factors which are all about the material itself such as microstructure, distortion, surface condition and external factors such as influence of blood flow, body temperature and pH value. The effect of grain refinement by various severe plastic deformation methods on the corrosion behaviour of materials has caught much attention in recent years. During the last decade, equal-channel angular pressing (ECAP) has considered as the most appropriate procedure for the fabrication of ultrafine-grained (UFG) metals and alloys for industrial application. It has been widely-known that ECAP process significantly affects the mechanical properties of Mg and its alloys. Although many studies have been done on the materials processed by ECAP, their corrosion resistance has been rarely reported [8]. The present work focused on the influence of microstructure change on corrosion resistance of AZ31 Mg alloy processed by ECAP.

Therefore, in this study, we attempted to investigate the immersion test on ECAPed AZ31 Mg alloy in RPMI 1640 medium that simulates the body's internal environment. The results would be helpful for better understanding the corrosion behaviours of ECAPed AZ31 Mg alloy and its alloys, and explore their possibility for engineering applications.

2. Experimental

2.1. ECAPed specimen preparation

The specimen used for ECAP process was cut from the extruded AZ31 Mg alloy round bar (99.96%). Fig. 1 shows the schematic illustration of the ECAP process. This billets as the specimen for ECAP with the size of diameter Φ6 mm × length 50 mm, were annealed for 24 hours at 723 K after cutting process. Then, the billets were repeatedly pressed for 8 passes with a plunger speed of 4 mm/s at two temperature conditions, 573K and 423K respectively. Molybdenum disulfide as lubricant was used to reduce the friction coefficient between the billet and the die inner wall. The billet was inverted and then rotated by 90° to the circumferential direction during the each pressing process.