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Impact of rare-earth elements on the corrosion performance of binary magnesium alloys

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ABSTRACT

The corrosion behaviour of Mg-0.3Ce, Mg-0.41Dy, Mg-0.63Gd, Mg-1.44Nd and Mg-1.43La (wt.%) alloys in 3.5 wt% NaCl solution was investigated using electrochemical tests. The as-cast microstructures of the Mg-RE alloys were characterized by the presence of second phases (Mg_xCe, $Mg_{41}Dy_5$, $Mg_{12}Gd$, $Mg_{12}Nd$, $Mg_{41}Nd_5$, $Mg_{24}Nd$ and $Mg_{12}La$) with different volume fraction and distribution. Results show that the corrosion mechanism was altered from uniform to localized corrosion mechanism depending on the specific RE alloying elements. The corrosion resistance of the Mg-RE alloys is increasing in the following order: Mg-1.43La, Mg-1.44Nd, Mg-0.3Ce, Mg-0.63Gd and Mg-0.41Dy. Accordingly, the corrosion morphology in the best resistant Mg-0.41Dy alloy and the worst Mg-1.43La alloy were observed and compared after 2h and 24 h of immersion using SEM-EDS, XPS and XRD analysis. The formation of the Dy_2O_3 oxide prevents the Mg-0.41Dy alloy from pitting corrosion and lead to an excellent corrosion surface even after 24 h of immersion. Meanwhile, the presence of a high fraction of the $Mg_{12}La$ phase along the grains boundaries in the Mg-1.43La alloy causes severe pitting corrosion by acting as anodic phase.

1. Introduction

During the last decades, the use of Magnesium (Mg) based alloys as structure materials in automotive and aerospace industries have been increased due to their low density, high specific strength, high damping capacity, corrosion resistance and easy recyclability [1–3]. However, Mg-based alloys generally suffer from relatively poor corrosion resistance in the high chloride environment of physiological systems due to their low standard electrochemical potential (−2.37 V), as compared to the SHE (Standard Hydrogen Electrode) [4] which therefore restricts their use in a variety of applications [5–7]. The poor corrosion resistance of Mg-based alloys was attributed to the internal galvanic corrosion by inhomogeneous distribution of second phases or the presence of impurities elements such Fe, Ni, Cu and Co and the instability of the hydroxide film $(MgOH)_2$ that formed on the Mg surface [5,6].

Many strategies have been proposed to improve the corrosion resistance of Mg-based alloys. Surface treatment by anodic coating is the most employed technique for improving the corrosion behaviour of Mg-based alloys [8–11]. Among the existing surface treatment methods, the plasma electrolytic oxidation (PEO) coating technique shows a remarkable increase in the corrosion resistance of Mg alloys by forming a relatively thick and crystalline oxide layer on the surface [8,12–14].

Fabricate ultrafine-grained materials using severe plastic deformation (SPD) such as equal channel angular pressing (ECAP), high pressure torsion (HPT) and groove pressing (GP) have proven their effectiveness to improve the homogeneity of the microstructure of Mg alloys as well as their corrosion resistance by dissolution of impurities and accelerating passivity of Mg-based

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