Corrosion Behavior of Rapidly Solidified Mg-Zn-Y Alloys in NaCl Solution

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Abstract

Compositional dependence of corrosion behavior of rapidly solidified Mg-rich Mg-Zn-Y alloys in NaCl aqueous solution has been investigated. Mg-Zn-Y ternary alloys containing small amounts of Zn exhibited low corrosion rate, although the $Mg_{98}Y_2$ *(at. %) binary alloy showed severe corrosion with violet evolution of hydrogen. The alloy with highest corrosion-resistance was* $Mg_{97.25}Zn_{0.75}Y_2$*, its corrosion rate was about 1 mm year*$^{-1}$ *in 0.17 M (1.0 wt. %) NaCl solution.* $Mg_{97.25}Zn_{0.75}Y_2$ *alloy exhibited passive region in anodic polarization curves when immersed in NaCl solution. Rapidly solidification and small amount of Zn addition may bring about an increase in electrochemical homogeneity of Mg-Zn-Y alloys, resulting in enhancement of corrosion resistance.*

Keywords : Magnesium alloy, Rare earth element, Zinc, Rapid solidification, Corrosion

1. Introduction

In the last decade, Mg alloys have been used in automotive, aerospace and electronic industries where weight reduction is a necessary requirement. In general, Mg alloys produced by traditional ingot metallurgy (I/M) processing exhibit lower strength, ductility, creep resistance and corrosion resistance. The application of rapid solidification (RS) processing to Mg alloys results in the reduction in grain and intermetallic particle sizes, extension of solid solubility, formation of a non-equilibrium phase, and improvement of chemical homogeneity with a consequent improvement of mechanical properties and corrosion resistance. For finding wide application of Mg alloys in various fields of industry, it is an urgent necessity for us to give higher corrosion resistance to alloys. Recently, it has been reported that RS Mg-Zn-Y alloys with long period ordered structure exhibited high strength and high corrosion resistance [1-3]. However, corrosion behavior of the RS Mg-Zn-Y alloys has not been clarified in detail yet.

In this study, compositional dependence of corrosion behavior of RS Mg-Zn-Y alloys in NaCl aqueous solution has been investigated. Furthermore, we made an attempt to improve electrochemical homogeneity in the Mg alloys by controlling alloy microstructure. Large-scaled RS Mg-Zn-Y bulk alloy with the optimum composition has been fabricated by rapidly solidified flaky powder metallurgy (RS FP/M) processing. Prior to fabrication of bulk alloys, we have performed the preliminary investigation using melt-spun ribbon of Mg-Zn-Y alloys in order to determine the optimum compositions for high corrosion resistance.

2. Experimental Procedure

Master alloy ingots of nominal composition, $Mg_{98-x}Zn_xY_2$ (x=0, 0.5, 0.75, 1, 1.25 at. %) were prepared by high frequency induction heating in an argon atmosphere. RS alloy ribbons were produced by a single roller melt-spinning method in an argon atmosphere. The alloy compositions were measured by inductively coupled plasma emission spectrometry (ICP). Heat treatment of the RS alloy ribbons was carried out in Pyrex glass ampoules filled with argon gas at temperatures ranging form 573 to 673 K. Large-scaled Mg-Zn-Y bulk alloy was prepared using RS FP/M processing. The RS alloy flakes were pressed into a copper billet. Flakes in copper billets were degassed at 523 K for 20 min. In order to consolidate the flakes, extrusion was performed at an extrusion ratio of 10 at 623 K and a ram speed of 2.5 mm s^{-1}.

The corrosion tests were carried out in 0.17 M (1.0 wt. %) NaCl aqueous solution at 298 K pH is 6.3-6.8. The dissolution rates were calculated from hydrogen evolution during immersion [3,4]. Anodic polarization was performed in 0.1 M NaCl aqueous solution at 298 K after immersed for 5, 60 and 120 min at open-circuit potential.

3. Results and discussion

Figure 1 shows the change in the corrosion rate of rapidly solidified Mg-Zn-Y alloys as a function of Zn content in 0.17 M (1.0 wt. %) NaCl solution open to air at 298 K. The $Mg_{97.25}Zn_{0.75}Y_2$ alloy exhibited the lowest corrosion rate of only 1 mm year^{-1}, although the corrosion rate of the $Mg_{98}Y_2$

binary alloy reached about 80 mm year^{-1}. A small amount of Zn addition to Mg-Y alloys enhanced the corrosion resistance, but the corrosion rate increased gradually with increasing Zn content, when Zn content is more than 0.75 at. % in Mg-Zn-Y alloys.

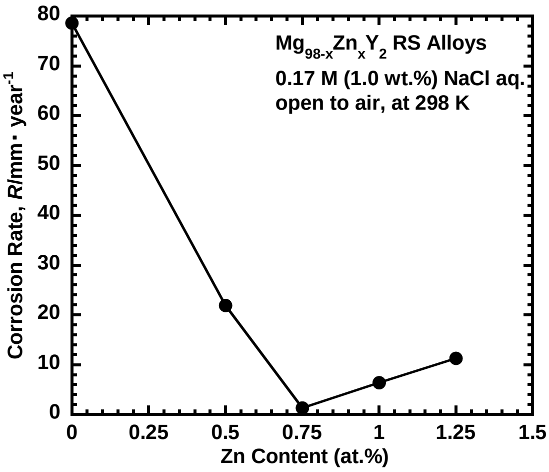

Fig. 1. Change in dissolution rate of Mg-Y and Mg-Zn-Y RS alloys as a function of immersion time in 0.17 M (1.0 wt. %) NaCl solution open to air at 298 K.

Figure 2 compares corrosion morphologies of the RS $Mg_{98}Y_2$ alloy immersed in 0.17 M (1.0 wt. %) NaCl solution for 15 min and RS $Mg_{97.25}Zn_{0.75}Y_2$ alloy immersed in 0.17 M (1.0 wt. %) NaCl solution for 60 min. The corroded surface of the $Mg_{98}Y_2$ alloy was characterized by localized attack. On the corroded surface of the $Mg_{97.25}Zn_{0.75}Y_2$ alloy, plate-like $Mg(OH)_2$ forms uniformly on the surface and grew perpendicularly to the substrate alloy.

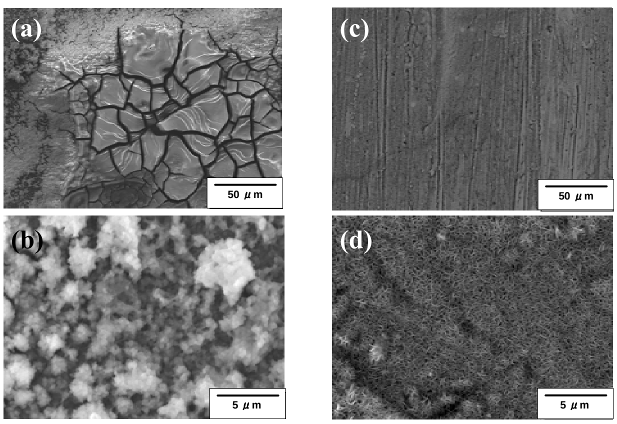

Fig. 2. SEM micrographs of $Mg_{98}Y_2$ RS alloy after15 min immersion and $Mg_{97.25}Zn_{0.75}Y_2$ RS alloy after 60 min immersion in 0.17 M (1.0 wt. %) NaCl solution.

Figure 3 shows potentiodynamic polarization curves of the rapidly solidified $Mg_{97.25}Zn_{0.75}Y_2$ alloy. Polarization curves had inflection points (allows in Fig.3). In the samples immersed for 5, 60, and 120 min, the inflection points appeared around the anodic polarization of -1500, -1440, and -1420 mV, respectively, after which the anodic current rapidly increased. The pseudo-passive region increased with increasing immersion time.

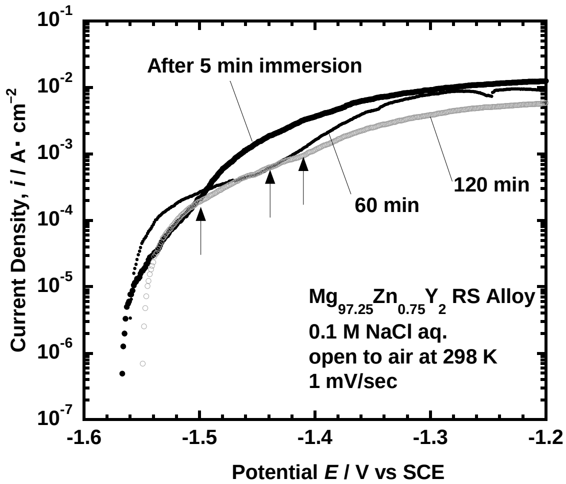

Fig. 3. Anodic polarization curves for $Mg_{97.25}Zn_{0.75}Y_2$ RS alloy after 5, 60 and 120 min immersion in 0.1M NaCl electrolytes. Arrows in the figure indicate inflection points.

4. Summary

Rapidly solidified Mg-Zn-Y ternary alloys containing small amounts of Zn exhibited low corrosion rate, although the $Mg_{98}Y_2$ (at. %) binary alloy showed severe corrosion with violet evolution of hydrogen.

Rapidly solidification and Zn addition may bring an increase in electrochemical homogeneity in Mg-Zn-Y alloys, resulting enhanced corrosion resistance.

5. References

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