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Effects of Y on microstructure and corrosion behavior of Mg-8Zn-4Al alloy

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Abstract. Effects of Y on microstructure of Mg-8Zn-4Al alloy was investigated by optical microscope (OM),X-ray diffractometry (XRD).The corrosion resistance behavior of Mg-8Zn-4Al-xY alloy immersed in 3.5% NaCl solution was tested by static weight loss and potentiodynamic polarization. The results showed that Mg-8Zn-4Al alloy with Y addition can refine grain size of the matrix and alter the distribution of the τ-$Mg_{32}(Al,Zn)_{49}$ phase from continuous network morphology transition to evenly distributed .The microstructure of Mg-8Zn-4Al-0.5Y alloy was finely refined, but no new phase was found.The new phase of Mg-8Zn-4Al-1.0Y alloy was $Mg_{24}Al_5Zn_2Y_{19}$. The corrosion potential value of Mg-8Zn-4Al alloy was increased with Y addition,while the corrosion current density was reduced. The corrosion resistance of Mg-8Zn-4Al alloy can be enhanced obviously with Y addition. The corrosion rate of Mg-8Zn-4Al-0.5Y alloy was the lowest compared with the other alloy in this test. Mg-8Zn-4Al-0.5Y alloy has the best corrosion resistance among of the four kinds alloy.

Introduction

Magnesium alloy has been investigated as metal structure material to replace heavier aluminum in manufacturing of mechanical components, because of its good processability,low density, high specific strength,light weight,thermal conductivity and so on[1].Magnesium alloys easily undergo galvanic corrosion in the corrosive environment,owing to the high reactivity of Mg substrate and the oxide film formed on the alloy surfaces can not act as an effective film[2].However,the poor corrosion resistance and high chemical reactivity of magnesium alloy have seriously limited their widely application in industry.Some previous[3,4] studies investigated that the effects of Y on microstructure and corrosion properties of Magnesium alloys and the results showed that magnesium alloy with Y addition can enhance mechanical properties and corrosion resistance. However, corrosion behavior of Mg-Zn-Al alloy system with Y addition has been rarely reported.In this work, Mg-8Zn-4Al-xY alloys were prepared,the microstructure and corrosion properties were studied.The purpose is to explore the effects of Y addition on microstructure and corrosion behavior of Mg-8Zn-4Al alloy.

Experimental

Pure magnesium(99.9 wt.%), pure aluminum(99.9 wt.%), pure zinc(99.9 wt.%), aluminum-10 wt.% manganese master alloy,aluminum-3.26 wt.% beryllium master alloy and Y were used to prepare for Mg-8Zn-4Al-xY alloys. The SG-5-12 crucible resistance furnace was used as the melting equipment. After all the charge melted, the molten alloy was poured into a steel mold which was preheated at 250℃.Microstructure of the alloys were observed by the XJ-16A optical microscope. Phase analysis was conducted by Y-2000 type X-ray diffraction(XRD) under CuKα radiation. Polarization curves experiments were carried out by using AUTO TEST PS-168 corrosion measurement system. Weight loss method was conducted to test the corrosion rate of magnesium alloy with 3.5% NaCl solution as corrosive medium. The corrosion rates were obtained by

$$V=(m_0-m_1)/A\cdot t. \qquad (1)$$

Where,V is the corrosion rate($g\cdot m^{-2}\cdot h^{-1}$),$m_0$ is the weight of of test sample before test(g),m_1 is the weight of test sample after test without the corrosion products(g),A is the sample area exposed to solution (m^2),and t is the exposure time(h).All the tests were performed at room temperature. Four kinds of alloys were prepared. The chemical compositions of the alloys are shown in Table 1.

Table1 Chemical composition of Mg-8Zn-4Al-xY alloy (wt%)

Alloy	Zn	Al	Y	Mn	Be	Mg
Mg-8Zn-4Al	8	4	0	0.25	0.01	Bal.
Mg-8Zn-4Al-0.5Y	8	4	0.5	0.25	0.01	Bal.
Mg-8Zn-4Al-1.0Y	8	4	1.0	0.25	0.01	Bal.
Mg-8Zn-4Al-1.5Y	8	4	1.5	0.25	0.01	Bal.

Results and discussion

Effects of Y on microstructure of Mg-8Zn-4Al alloy.

Optical microstructure of Mg-8Zn-4Al-xY alloy are given in Fig.1.It is found that the microstructure of Mg-8Zn-4Al alloy mainly consists of α-Mg and reticular second phase. As previously reported [5] that the room temperature structure of Mg-8Zn-4Al alloy was composed of α-Mg phase, τ-$Mg_{32}(Al,Zn)_{49}$ phase and φ-$Al_2Mg_5Zn_2$ phase, and the φ phase was very difficult to observe under low magnification microscope. It can be seen from Fig.1(a),the microstructure of Mg-8Zn-4Al alloy without Y was composed of α-Mg, a larger network structure phase of τ-$Mg_{32}(Al,Zn)_{49}$.With the addition of rare earth element Y, the microstructure of Mg-8Zn-4Al alloy has changed significantly. The change trend of the microstructure of the alloy was refinement first,then the microstructure of the alloy was became coarsening.The microstructure of Mg-8Zn-4Al-0.5Y alloy was finely refined,no new phase was found.All of the continuous network structure was broken into granular as shown in Fig.1(b).Then,with the increase content of Y, the microstructure of Mg-8Zn-4Al-xY alloy was coarsened gradually,and the granular structure of the fracture began to become continuous or semi-continuous.When adding 1.0% Y, a small portion of the block new phase can be observed in Fig.1(c). The microstructure of Mg-8Zn-4Al-1.0 alloy is thicker and the network structure is larger than that of Mg-8Zn-4Al-0.5Y alloy.When the content of Y addition reached 1.5%, the coarse and continuous structure can be seen in Fig.1(d).

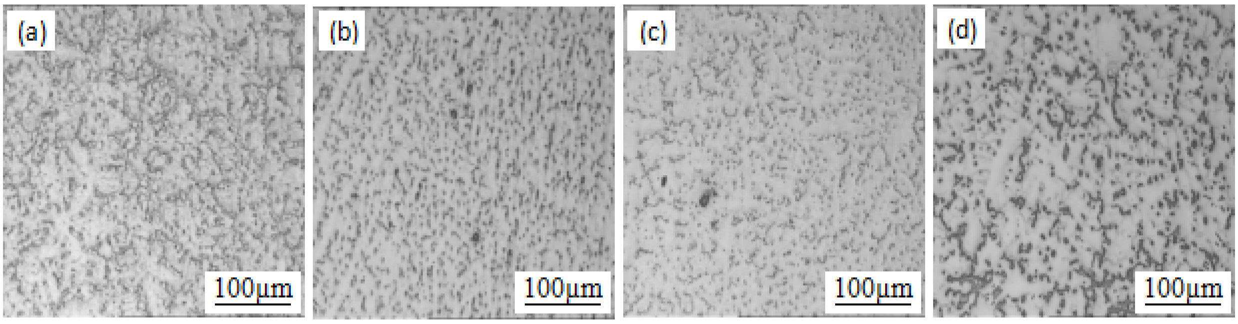

Fig.1 Microstructure of Mg-8Al-4Zn-xY alloy
(a) without Y; (b) 0.5% Y;(c) 1.0% Y; (d) 1.5% Y

The XRD results of Mg-8Zn-4Al-0.5Y alloy and Mg-8Zn-4Al-1.0Y alloy are shown in Fig.2.The XRD analysis were detected to further identify the chemical component and the results showed that no new phase was formed of Mg-8Zn-4Al-0.5Y alloy but the new phase of Mg-8Zn-4Al-1.0Y alloy was $Mg_{24}Al_5Zn_2Y_{19}$. Y is one of the activity element on the surface of magnesium,when adding Y to Mg-8Zn-4Al alloy,the rare earth element Y was first enriched at the grain boundary, thereby suppressing the growth of the $Mg_{32}(Al,Zn)_{49}$ phase.The microstructure of Mg-8Zn-4Al alloy was refined after adding Y.

Corrosion behavior of Mg-8Zn-4Al-xY alloy.

The corrosion rate of Mg-8Zn-4Al-xY alloy immersed in 3.5% NaCl solution for 24h, 48h, 72h, 96h and 120h are shown in Fig.3. It can be found that the corrosion rate of Mg-8Zn-4Al alloy was much larger than that of Mg-8Zn-4Al-0.5Y alloy, Mg-8Zn-4Al-1.0Y alloy and Mg-8Zn-4Al-1.5Y alloy.The corresponding corrosion rate of the four kinds alloy immersed in 3.5% NaCl solution for 120h reached the maximum value.With the increase of corrosion time,the corrosion rate of Mg-8Zn-4Al-xY(x is 0.5,1.0,1.5,respectively) alloy was showed the upwarding tendency. For all the alloys with Y addition, the corrosion rate of Mg-8Zn-4Al-1.5Y alloy was the fastest, followed by Mg-8Zn-4Al-1.0Y alloy and Mg-8Zn-4Al-0.5Y alloy.The corrosion rate of Mg-8Zn-4Al-0.5Y alloy was the lowest,and Mg-8Zn-4Al-0.5Y alloy had the best corrosion resistance manifestation of the four kinds alloy. It can be clearly seen that Mg-8Zn-4Al alloy had the maximum corrosion rate change value between the time span of 96h to 120h, while the corrosion rate of Mg-8Zn-4Al-xY(x is 0.5,1.0,1.5, respectively) alloy changed relatively flat.In summary, the corrosion rate of Mg-8Zn-4Al-xY(x is 0.5,1.0,1.5,respectively) alloy changed relatively slower with the increasing time, and the corrosion rate reached to the maximum value at 120h and they were lower than Mg-8Zn-4Al alloy without Y addition.

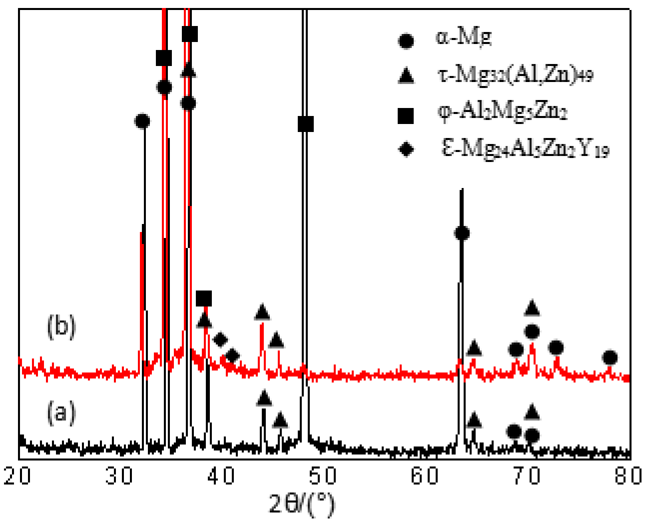

Fig.2 XRD patterns of Mg-8Zn-4Al-xY alloy
(a)x=0.5 (b) x=1.0

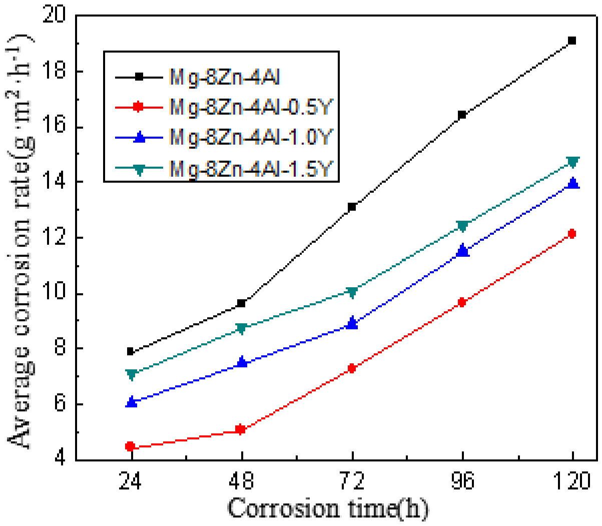

Fig.3 Corrosion rate of alloys immersed in 3.5%NaCl solution for different time

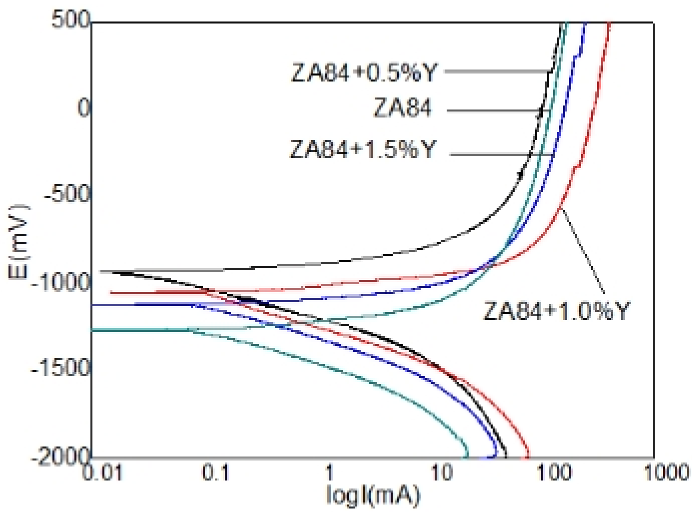

Fig.4 Electrochemical polarization curves of Mg-8Zn-4Al-xY alloy

The electrochemical corrosion of Mg-8Zn-4Al alloy was tested in 3.5wt.% NaCl solution. In this experiment the typical polarization curves of Mg-8Zn-4Al-xY alloy were shown in Fig.4. It can be seen from Fig.4, adding Y to Mg-8Zn-4Al alloy has effect on the anodic process of the alloy. The more positive the corrosion potential is, the higher corrosion resistance of the alloy has to be corroded[6]. The corrosion potential of Mg-8Zn-4Al alloy with Y addition was found to be higher than that of the Mg-8Zn-4Al alloy without Y addition.The corrosion potential and the corrosion current density of Mg-8Zn-4Al-xY alloy exhibited significant differences separately.The electrochemical results of Mg-8Zn-4Al-xY alloy were displayd in Table 2.It showed that the corrosion potential value of Mg-8Zn-4Al alloy was increased with Y addition.The corrosion resistance of alloy is proportional to its current density, the smaller the current density is, the better the corrosion resistance is[6].The corrosion current density value of Mg-8Zn-4Al alloy was decreased when adding Y. It showed that Mg-8Zn -4Al-0.5Y alloy has the best corrosion resistance in the four kinds of alloy.The results indicated that corrosion resistance of Mg-8Zn-4Al alloy can be enhanced obviously with Y addition.

Table 2 The electrochemical corrosion data of Mg-8Zn-4Al-xY alloy

Alloy	E_{Corr}(mv)	J_{corr}($mA\cdot cm^{-2}$)
Mg-8Zn-4Al	-1450	1.9010
Mg-8Zn-4Al-0.5Y	-1109	0.9518
Mg-8Zn-4Al-1.0Y	-1242	1.3419
Mg-8Zn-4Al-1.5Y	-1269	1.5308

Conclusions

Adding Y to Mg-8Zn-4Al alloy, all of the continuous network structure was broken into granular,and the microstructure of Mg-8Zn-4Al alloy was refined after adding Y.The microstructure of Mg-8Zn-4Al-0.5Y alloy was finely refined, but no new phase was found.The new phase of Mg-8Zn-4Al-1.0Y alloy was $Mg_{24}Al_5Zn_2Y_{19}$.

The corrosion potential value of Mg-8Zn-4Al alloy was increased with Y addition,while the corrosion current density was reduced. The corrosion resistance of Mg-8Zn-4Al alloy can be enhanced obviously with Y addition. The corrosion rate of Mg-8Zn-4Al-0.5Y alloy was the lowest compared with the other alloy in this test. Mg-8Zn-4Al-0.5Y alloy has the best corrosion resistance among of the four kinds alloy.

Acknowledgments

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