COATING PROPERTIES OF ELECTROLESS Ni-P PLATING ON MAGNESIUM ALLOY WITH CERIUM CHLORIDE

In order to improve the corrosion resistance of magnesium alloy, Ni-P coating was prepared on the surface of AZ91D magnesium alloy by chemical deposition method, and the optimum process of electroless Ni-P plating was determined. In this experiment, Scanning electron microscope (SEM) and Autolab electrochemical workstation were used to study hardness, microscopic morphology and corrosion resistance of the coating. The results showed that Ni-P coatings have better corrosion resistance in 3,5 % NaCl solution under the condition: $CeCl_3$ 0,15 / g/L, $NiSO_4$ 28 / g/L, Na_2HPO_3 25 / g/L, temperature 85 / °C and pH = 7,3. The corrosion rate of the coating decreases first and then increases with increasing amount of Cerium chloride.

Key words: coating, magnesium alloys, cerium chloride, microhardness, corrosion resistance

INTRODUCTION

Magnesium alloy has the advantages of softness, high strength, excellent workability and thermoforming performance, excellent shock absorption performance, good electromagnetic compatibility and recyclability, but its poor corrosion resistance limits its application range[1-3]. To increase the corrosion resistance of magnesium alloys, many researchers have conducted extensive research [4-6], including zinc leaching, direct electroless Ni-P alloy plating, etc[7-11]. Ni-P coating was prepared on the surface of AZ91D magnesium alloy by electroless plating method. Ni-P coating on the surface of AZ91D magnesium alloy was prepared by chemical deposition method, and add $CeCl_3$ in the bath. The effect of microstructure and corrosion resistance of the coating was investigated by scanning electron microscope (SEM), Vickers hardness tester, and chemical deposition method using Autolab electrochemical workstation. It identifies the best process for electroless Ni-P plating and provides a reference for the theoretical study of magnesium alloys.

EXPRIMENTAL PROCEDURE

The material used in this experiment is AZ91D magnesium alloy. Its size is 55 / mm×10 / mm×10 / mm (see Table 1) . The experimental procedure includes sandpaper polishing, alkali cleaning, acid activation, electroless plating, cleaning, and weighing.

The surface of the magnesium alloy was polished with water sandpaper, then rinsed with deionized water

M. L. Xu, S. M. Kang,kangshumei_911@163.com, T. T. Chen: School of Materials and Metallurgy, University of Science and Technology LiaoNing, Anshan, Liaoning, China
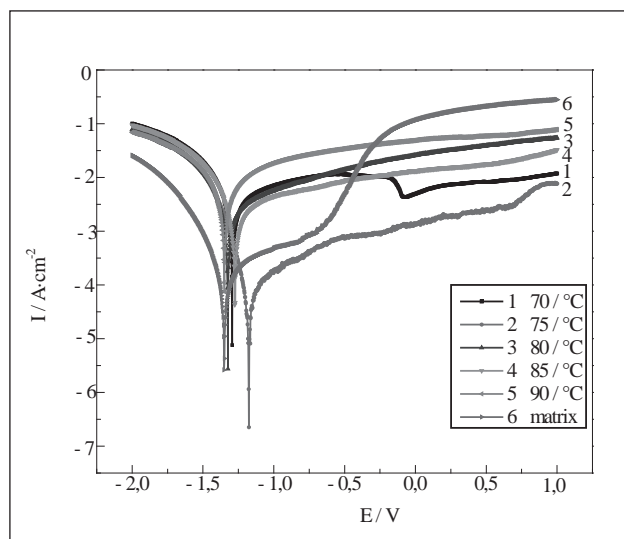
and used. The smooth substrate was placed in a constant temperature water bath at 70 / °C and placed in alkaline degreasing solution for 5 / mins to remove any residual impurities on the substrate (The alkaline degreasing method in this article is to first use 20 / g/L sodium hydroxide solution for saponification, and then add 20 / g/L sodium carbonate solution to buffer). The magnesium alloy is subjected to alkaline degreasing followed by acidification with a 10 / % HF solution. The immersion time is approximately 5 / minutes to form a magnesium fluoride protective film.

The pickled sample was placed in the bath. Finally, rinse with deionized water at 85 / °C, rinsed dry at room temperature and measured its mass. The surface hardness of the Ni-P alloy coating was measured using a Vickers hardness tester. Three points were randomly selected on the plated magnesium alloy for testing.

The corrosion potential, corrosion current, and coating were measured using an Autolab electrochemical workstation. The relationship between corrosion resistance, corrosion potential, corrosion current, and impedance was obtained by analyzing these data.

Table 1 Chemical composition of AZ91D / wt./%

Mg	Al	Zn	Mn
Mar	8,5-9,5	0,45-0,9	0,1-0,4
Si	Cu	Ni	Fe
≤0,05	≤0,025	≤0,001	≤0,004

RESULTS AND DISCUSSION
Effect of different temperatures on Ni-P plating

Figure 1 is a polarization curve at different temperatures. As the temperature of the bath increases, the cor-

Figure 1 Polarization curves at different temperatures

rosion potential of the coating increases first and then decreases. The highest corrosion potential occurs when the temperature reaches 85 / °C. The corrosion current density decreases first, increases again, and then decreases. The effect of temperature on corrosion resistance is due to its effect on the plating rate. At temperatures below 85 / °C, the bath temperature is low, the plating rate is slow, and the plating is thin. At temperatures above 85 / °C, self-decomposition of the bath occurs. As a result, the quality of the plating is reduced, which affects the corrosion resistance.

Effect of Ni-P plating under different pH conditions

As shown in Figure 2, as the pH of the plating solution increases, the corrosion potential of the coating first increases and then decreases. At a pH of 6,8, it reaches a maximum value, the corrosion current density decreases first, and then increases substantially, at a pH of 7,3. When it reaches the minimum, the corrosion resistance is the highest, so the corrosion resistance is best
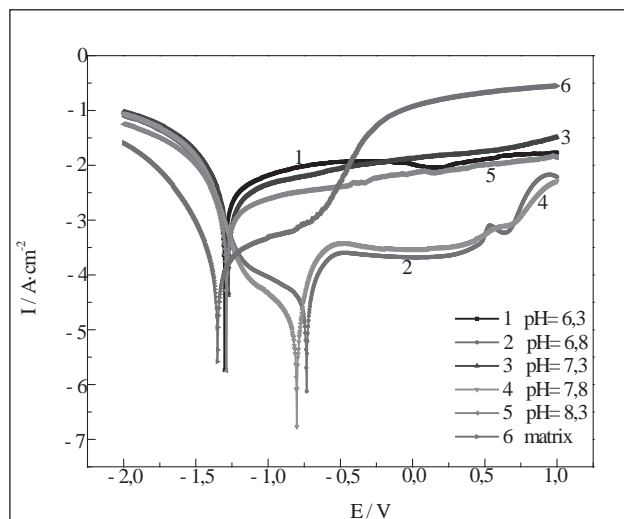

Figure 2 Polarization curves at different PH

when the pH is 7,3. The effect of pH on electroless plating is the formation of two phosphites in the bath. When the pH is lower, the H^+ produced in the bath is less than the H^+ produced in the bath with higher pH, and the stability of the bath is better. When the pH is increased, it is beneficial to increase the plating speed, but the plating is faster. The stability of the liquid is unfavorable, thereby affecting the quality and adhesion of the coating and further affecting the corrosion resistance.

Corrosion resistance test

Figure 3 shows the polarization curves of $CeCl_3$ with different concentrations. From Figure 3, With the increase of rare earth $CeCl_3$ concentration, the corrosion potential of the coating first increases and then decreases, and the corrosion current density increases first and then decreases. Analyze the reasons, with the increase of $CeCl_3$ concentration, Ce^{3+} reduces the surface activation energy, increases the nucleation rate, and improves the plating rate, the coating quality is improved, and the corrosion resistance is improved. However, excessive Ce^{3+} is adsorbed on the surface of the substrate, which
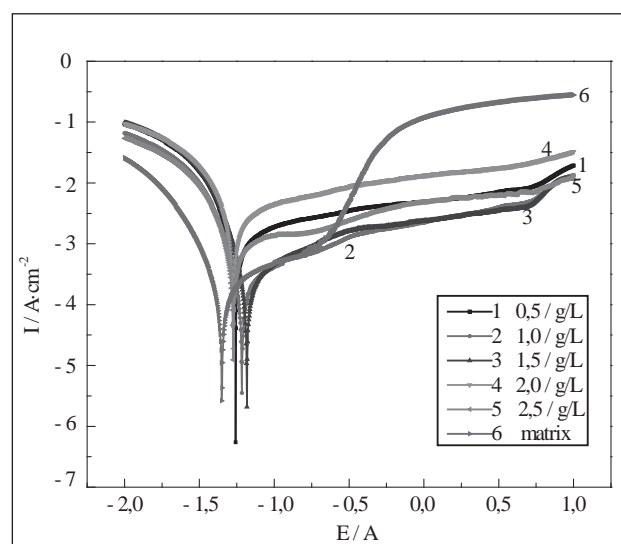

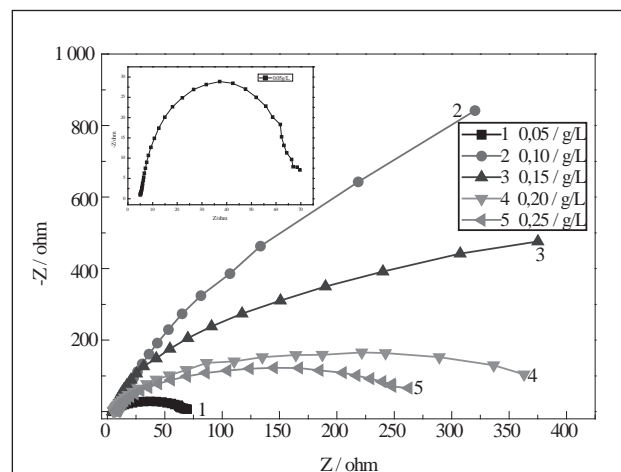**Figure 3** Polarization curves of different concentrations of $CeCl_3$

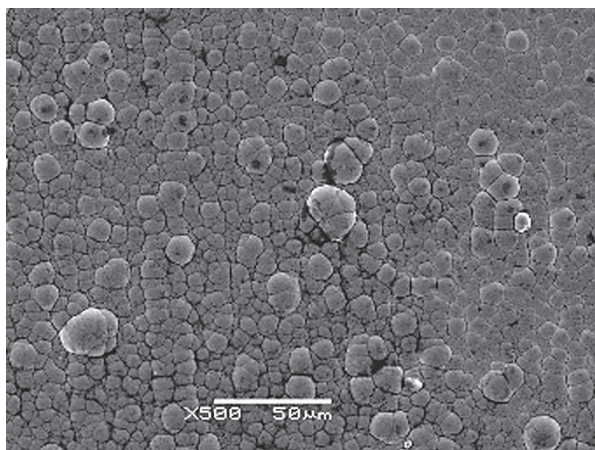**Figure 4** Impedance plots of different concentrations of $CeCl_3$

Figure 5 SEM images of microstructure of 0,15 / g/LCeCl$_3$

hinders the deposition of the plating layer, decreases the plating rate, decreases the quality of the plating layer, and reduces the corrosion resistance. When the concentration of CeCl$_3$ is 0,15 / g/L, the surface deposition rate of Ni-P alloy coating is larger, the hardness of the coating is larger, and the corrosion current density is the maximum.

Coating spectra analysis of different CeCl$_3$ concentrations

Figure 5 shows SEM images of the micro-morphology of CeCl$_3$ 0,15 / g/L coatings. It can be seen from Figure 5 that the microstructure of the electroless Ni-P alloy coating is a typical ball-shaped structure. With the increase of the concentration of the solution, the grains of the coating first increase and then remain basically unchanged. When the concentration of CeCl$_3$ is 0,15 / g/L, there are no obvious holes and gaps on the surface of the coating, and the coating prepared under the conditions of other CeCl$_3$ concentrations is denser, and the crystal grains are evenly distributed, and the boundaries between the crystal cells are clear.

CONCLUSIONS

1) As the bath temperature increases, the corrosion potential of the coating first increases and then decreases, indicating that the corrosion resistance is best at a temperature of 85 / °C.

2) With the increase of PH, the corrosion potential of the coating first increases and then decreases. When the pH is 7,3, the corrosion resistance is best.

3) As the concentration of rare earth CeCl$_3$ in the bath increases, the corrosion potential of the coating first increases and then decreases, and the corrosion current density rises first and then decreases. The corrosion resistance is best when the concentration reaches 0,15 / g/L. The addition of rare earth elements makes the nickel-phosphorus grains in the coating be refined, the resulting coating is more dense, and its corrosion resistance is higher than that of the matrix.

4) The addition of CeCl$_3$ to the plating solution makes the plating grains finer and more uniform. According to the experimental results, when the concentration of CeCl$_3$ is 0,15 / g/L, the surface deposition rate of Ni-P alloy coating is better, the hardness is greater, and the coating performance is optimal.

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REFERENCES

[1] L.Xiao, A study on wear resistance of the Ni-P-SiC coating of Magnesium Alloy. Intelligent Information Technology Application Association, Mechanical Intelligent Information Technology Application Association, (2011),1,6-8.

[2] M.J.Li, Z.Y.Li, S.L. Zhang, Study on electroless Ni-P alloy plating on magnesium alloys,Electroplating and finishing, (2009), 11,11-13.

[3] S.S.Li, J.Ma, P.Jia, The surface chemical vapor deposition tungsten plating process of AZ31 magnesium alloy and its corrosion resistance and abrasion resistance，China surface engineering, 27 (2014), 1 , 40-44.

[4] H.F.Shi, X.H.Jiang, Research status of electroless ni-p plating on magnesium alloys，Electroplating and environmental protection, (2008), 1,1-3.

[5] Z.Ma, F.H.Sun, W.Q.Hu, Study on the technology of electroless Ni-P plating on magnesium alloys，Surface technology, (2005), 6,45-47.

[6] H.Y.Yang, G.H.Wu, W.J. Ding, Research status of electroless Ni-P alloy plating on magnesium alloys Electroplating and finishing, (2008), 3,16-20.

[7] M.Zhao, G.G.He, D.H.Sun, Study on the structure and corrosion resistance of AZ91D magnesium alloy multiplex conversion film, Surface technology, 38 (2009), 2, 28-30.

[8] Z.Q. Cai, P. Liu, Z.G. Shao, Preparation and properties of AZ91D magnesium alloy tin salt conversion film, Electroplating and environmental protection, 35(2015), 6,30-33.

[9] Vyasaraj Manakari, Gururaj Parande, Manoj Gupta, Selective Laser Melting of Magnesium and Magnesium Alloy Powders: A Review Department of Mechanical Engineering, National University of Singapore, 23(2016), 1,60-64.

[10] Y.N.Gou, W.J.Huang, R.C.Zeng, Y. Zhu, Research status of electroless ni-p alloy plating on magnesium alloys, Transactions of Nonferrous Metals Society of China, 20 (2010), S2,674-678.

[11] L. J.Yang, G.C.liu, S.L.Wang, Application of Ni-Cu-P alloy plating on gas condensing heat exchangers Electrochemistry, 14 (2008), 3,325-329.

Note: The responsible translator for English is X.L. Fu, University of Science and Technology Liaoning, Anshan, China.