CORROSION RESISTANCE OF AZ91 MAGNESIUM ALLOY WITH PULSE ELECTRODEPOSITED NI-SIC NANOCOMPOSITE COATING

M. Hajiali Fini, A. Amadeh

School of Metallurgy & Materials Engineering, College of Engineering,
University of Tehran, Tehran, Iran

ABSTRACT

Magnesium and its alloys are the lightest of the structural metals, which makes them one of the most promising materials to minimize vehicle weight, but poor surface properties restrict the application of these alloys. In this paper, Ni-SiC nanocomposite coatings were applied on AZ91 magnesium alloy from Watts bath with SiC content 0 g.L-1 (pure Ni), 10 g.L-1 (Ni-10SiC) and 15 g.L-1 (Ni-15SiC) by application of pulse electrodeposition technique. The morphology and phase analysis were carried out by Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) analysis, respectively. Micro-hardness of specimens was measured and the results revealed a significant enhancement: from 74 Vickers for bare AZ91 magnesium alloy to 523 Vickers for coated specimen in the bath containing 15 g.L-1 SiC. The Corrosion behavior of the samples was studied by potentiodaynamic polarization, and the obtained data showed the superior corrosion resistance for the coated AZ91 magnesium alloy, i.e. the corrosion current density decreased from 2.69 mA.cm-2, for the uncoated sample, to 0.00046 mA.cm-2, for coated specimen in the bath containing 15 g.L-1 SiC and the corrosion potential increased from -2.069 V to -0.33 V for the same conditions.

Key words: nanocomposite coating, pulse electrodeposition, SiC Concentration, corrosion, micro-hardness

INTRODUCTION

Due to high specific strength of magnesium, magnesium and magnesium alloys are being widely used in automotive and nonautomotive industries [1]. However, the application of these alloys has been restricted because of the poor corrosion properties. the Corrosion resistance improvement of these alloys has been subjected to the lots of researches in recent years [2]. Application of appropriate coatings on these alloys is one the most applicable procedures for improving the corrosion behavior of magnesium, the Coatings such as Ni, Cr etc [3, 4]. These coatings can be reinforced by hard particles such SiC, Al_2O_3, TiO_2 etc [5-7]. Among these composite coatings, Ni-SiC is one the most promising corrosion resistant coatings which have been used on different alloys [8, 9].

In this study, the corrosion improvement of AZ91 magnesium alloy by application of Ni-SiC nano composite coating was investigated. For this aim, different coatings, from solute on with different SiC content, were applied on the alloy and the Corrosion behavior of each one was studied.

METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

The substrate material used was AZ91 as cast magnesium alloy with a size of 20mm×20mm×5 mm. The chemical composition of the alloy is given in *Table 1*. The samples were abraded with No. 2000 SiC paper before the pretreatment processes. The Zinc immersion coating was used as the pretreatment [10].

Table 1 - Chemical composition of AZ91 magnesium alloy.

Al (% wt)	Zn (% wt)	Mn (ppm)	Fe (ppm)	Mg
9	1	0.17	0.01	Balanced

The coatings were prepared from Watts solution. The Ni-SiC layers was electrodeposited from a suspension of SiC nano particles (*Fig. 1*. TEM photograph of SiC particles with average grain size of 40 nm) in the bath. The compositions of the bath and the operating conditions have been shown in *Table 2*. To adjust the PH of the bath, NaOH and H2SO4 were used for increasing and decreasing, respectively.

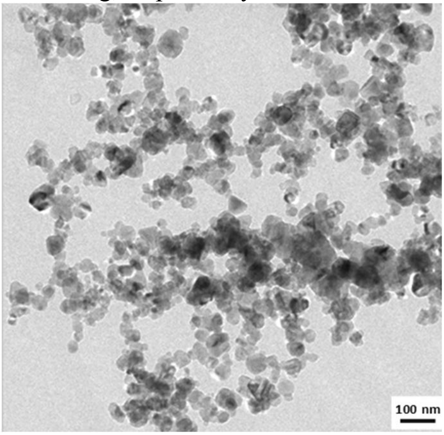

Fig. 1 - TEM photograph of SiC particles (curtsey of Hefei Kaier Nanometer Energy & Technology Co., Ltd)

Electrodeposition of Ni–SiC composite coatings was performed under square pulse current conditions in which the duty cycle is defined as Ton/(Ton +Toff), where Ton is the on-time period and Toff is the off-time period of the imposed pulses. After two hours electroplating, the thickness of the coatings was measured as 30 μm.

SEM investigations were carried out using a Philips XL30 instrument on the samples while a thin layer of gold was deposited on them. XRD investigations were conducted using a Philips X'pertPro instrument with CuKα radiation. The potentiodynamic polarization tests were performed by suspending the samples in 3.5% NaCl solution. The counter and reference electrodes were platinum and Saturted Calomel Electrode (SCE), respectively. After about one hour stabilization at rest potential, polarization test commenced at a scan rate of 1 mV/s using an EG&G273 instrument.

Table 2 - Chemical composition and operating condition of electroplating solution

Item	value
$NiSO_4.7H_2O$	300 g.L^{-1}
$NiCl_2.6H_2O$	45 g.L^{-1}
H_3BO_3	45 g.L^{-1}
Sodium Dodecyl Sulfate (SDS)	1 g.L^{-1}
Saccharin	1 g.L^{-1}
SiC	5 g.L^{-1}
Current Density	50 mA.cm^{-2}
PH	4.5
Temperature	50 °C

The corrosion current density was determined by varying ± 20 mV around the EOCP. Vickers micro-hardness of the magnesium alloy and the coatings were evaluated using a micro-hardness tester with Vickers indenter, at a load of 200 g and duration of 30 s. For each specimen, the average hardness value was taken from at least 3 tests.

RESULTS AND DISCUSSION

The cross section of coated AZ91 has been shown in *Fig. 2*. The good adhesion of the coating is seen. The results of micro-hardness of the specimens have been illustrated in *Fig. 3*.

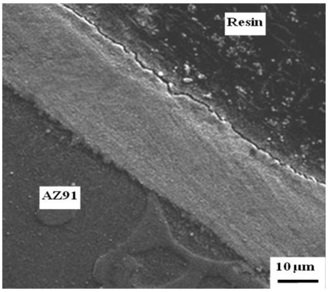

Fig. 2 – SEM photograph of cross section of coated AZ91

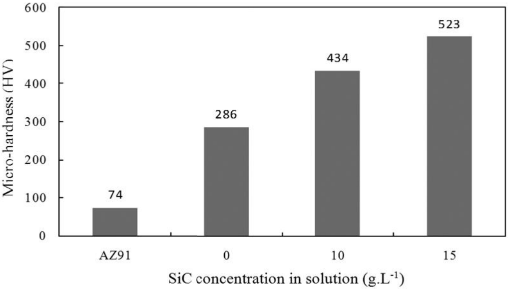

Fig. 3 – Micro-hardness of the coatings with different SiC concentration in solution

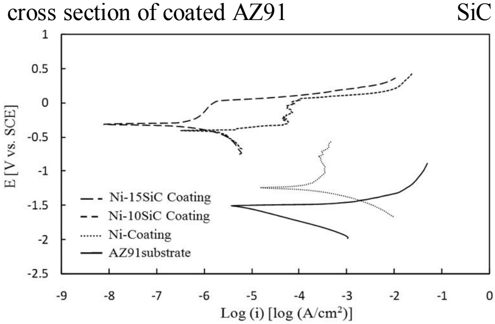

Fig. 4 – Polarization curves of bare magnesium alloy substrate, pulse electrodeposited Ni coating, Ni–10SiC (doposited from the bath containing 10 g.L^{-1} SiC) and Ni–15SiC (doposited from the bath containing 15 g.L^{-1} SiC) nanocomposite coating in 3.5 wt.% NaCl solution

It can be seen that applying the Ni coating causes a significant enhancement and as the SiC concentration in the bath increases, the micro-hardness improves.

The data from polarization test has been brought in *Fig. 4*. As it can be observed, the application of the coating makes the AZ91 more corrosion resistance and the embedded SiC nano particles lead to considerable reduction in the corrosion current density and also shift the Corrosion potential to more positive value.

CONCLUSIONS

To improve the corrosion resistance of AZ91 magnesium alloy, the Ni and Ni-SiC nanocomposite coatings were applied on the alloy by pulse electrodeposition. The major results attained from experimental studies can be summarized as:

- The micro-hardness of bare AZ91 alloy was 74 Vickers, and increased to 523 Vickers for the coating applied from the bath containing 15 g.L-1 SiC.
- The corrosion potential increased from -2.069 V, for AZ91 alloy to -0.33 V for the coating applied from the bath containing from 15 g.L-1 SiC.
- The corrosion current density reduced i.e. the corrosion resistance of coated AZ91, improved about 5600 %

REFERENCES

[1] B.L. Mordike, T. Ebert, Journal of Materials Science and Engineering, 2001, A 302, P. 37-45.
[2] Zhong-hou LI, Zhi-yong CHEN, Sha-sha LIU et al. Trans. Nonferrous Met. Soc., 2008, China 18.
[3] Changdong Gu, Jianshe Lian, Guangyu Li, Liyuan Niu, Zhonghao Jiang, Journal of Alloys and Compounds, 2005, 391, P. 104–109.
[4] W.X. Zhang, N. Huang, J.G. He et al. Journal of Applied Surface Science, 2007, 253, P. 5116–5121.
[5] A. Araghi and M.H. Paydar, Journal of Materials and Design 2010, 31, P. 3095–3099.
[6] P. Rodrigo, M. Campo, B. Torres et al. Journal of Applied Surface Science, 2009, 255, P. 9174–9181.
[7] Shiyan Zhang, Qing Li, Xiaokui Yang et al. Journal of Materials Characterization, 2010, 61, P. 269-276.
[8] K.H. Hou, M.D. Ger, L.M. Wang and S.T. Ke, Journal of Wear, 2002, 253 P. 994–1003.
[9] A.F. Zimmerman, D.G. Clark, K.T. Aust and U. Erb, Journal of Materials Letters, 2002, 52, P. 85–90.
[10] ASTM B 480, Annu. Book ASTM Stand., 2003, 02.05, Section 2.