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Effect of Na_2SiO_3 Concentration on the Properties of AZ31 Magnesium Alloy Prepared by Electrolytic Plasma Processing

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The effect of Na_2SiO_3 concentration on the dense ceramic oxide coatings prepared on a AZ31 magnesium alloy through electrolytic plasma processing in a NaOH-Na_2SiF_6 electrolytic solution, have been investigated. The x-ray diffraction (XRD) results showed that the coating formed in silicate electrolyte was mainly composed of MgO, Mg_2SiO_4. Scanning electron microscopy (SEM) micrographs reveals that the number of pores on coatings decreases by increasing concentration of Na_2SiO_3 and coatings prepared in 12 - 20 g/L of Na_2SiO_3 show similar surface morphologies. The observed micro-hardness of coating layers is over 1000 Hv, which is much larger than that of the original AZ31 magnesium alloy without electrolytic plasma processing.

Keywords: electrolytic plasma processing, plasma electrolytic oxidation, AZ31, magnesium alloy

1. INTRODUCTION

Exploration of properties of inorganic material has been a long-standing goal in the development of functional materials.[1-3] Magnesium and its alloys are widely used in marine, construction, aerospace, automobile and communication industries as the lightest of currently used construction metals.[4,5] But its poor properties in corrosion resistance, wear resistance, hardness and so on, limited its application. To overcome this problem, electrolytic plasma processing (EPP), as an environmental friendly technique developed from anodic oxidation, has been used to do surface modifications on magnesium alloys in recent years.[6,7] By using this method, the wear and corrosion protective ceramic coatings can be fabricated on valve metals such as Al, Mg, and Ti.[8-13] During EPP process, oxide coatings are broken down by high voltage and complicated reactions occur in the discharge channels. As a result, thick, hard, well-adhered ceramic coating layers with high corrosion and wear resistance are formed on magnesium alloys.[14,15] Properties of coating layers formed by EPP depended on composition and concentration of electrolyte. Therefore, the selection of electrolyte concentration is an important aspect in EPP. In this work, NaOH-Na_2SiF_6 based electrolytes with various concentrations of Na_2SiO_3 were used and the microstructure and mechanical properties of the coatings were investigated.

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2. EXPERIMENTAL PROCEDURE

AZ31 magnesium alloys [wt.%, Al (2.5 - 3.5), Zn (0.6 - 1.4), Mn (0.2 - 1.0), Si $\leq$ 0.1, Fe $\leq$ 0.005, Cu $\leq$ 0.05, Ni $\leq$ 0.005, and Mg balance] with dimension of D 30mm × H 10mm and surface roughness of Ra $\leq$ 0.1 μm were used as the substrate material. All the samples were degreased with acetone, alcohol and DI water in ultrasonic bath. The EPP was carried out in NaOH (2 g/L)-Na_2SiF_6 (0.5 g/L) based electrolyte with different concentration of Na_2SiO_3 (2 - 20 g/L) under the hybrid-voltage (DC260V + AC200V) for 30 min. EPP equipment is composed of teflon bath, power supply, cooling system, circulating pump and electrolyte. Stainless steel was used as the cathode and an AZ31 Mg alloys were used as the anode. Microstructure and phase of coatings were examined by JP/JSM 5200 scanning electron microscopy (SEM) and X'pert MPD 3040 x-ray diffractometer. Mechanical properties were measured by Vickers hardness and wear-resistance test.

3. RESULTS AND DISCUSSION

Figure 1 shows the surface morphologies of ceramic coatings fabricated by EPP on AZ31 magnesium alloys in NaOH-Na_2SiF_6 electrolyte with different concentration of Na_2SiO_3. The coatings show pores distribution all over the surface. Number of pores on coatings decreases by increasing the concentration of Na_2SiO_3 from 2 to 12 g/L, and show similar surface morphologies with further increase in concentration. The different surface morphologies of the coatings may be attributed to the different discharge characteristics with different concentration of Na_2SiO_3.[16]

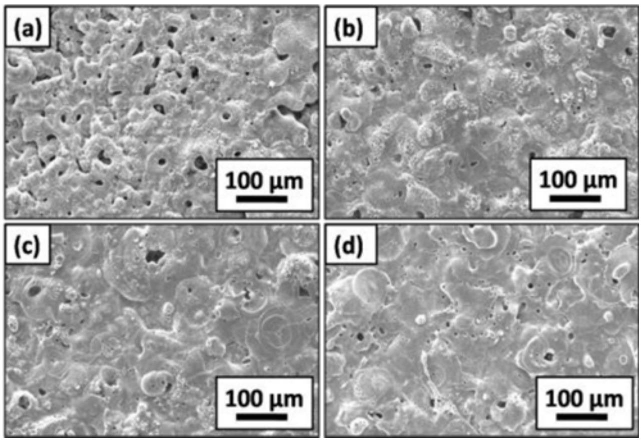

Fig. 1. surface morphologies of the ceramic coatings prepared with different concentration of Na_2SiO_3 (a) 2 g/L, (b) 8 g/L, (c) 12 g/L, and (d) 20 g/L.

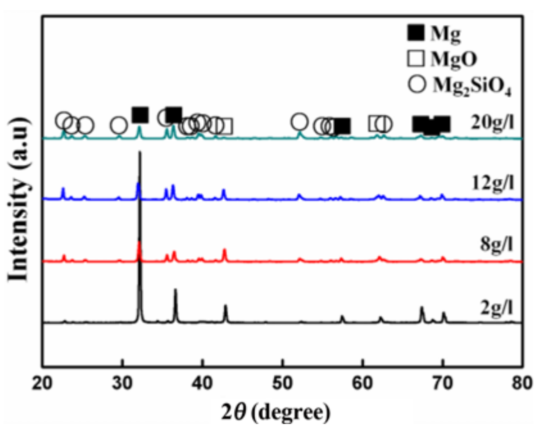

Fig. 2. X-ray diffraction patterns of EPP coated AZ31 alloys with different concentration of Na_2SiO_3 electrolyte.

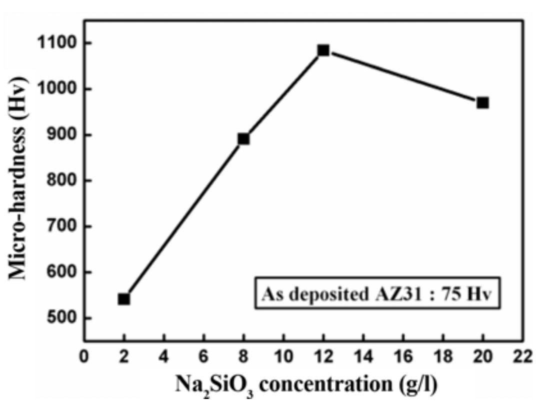

Fig. 3. Micro-hardness result of ceramic coatings prepared with different Na_2SiO_3 concentration of electrolyte.

Figure 2 shows the XRD spectra of the ceramic coatings prepared on AZ31 Mg alloy by EPP in NaOH (2 g/L) - Na_2SiF_6 (0.5 g/L) based electrolyte with different concentration of Na_2SiO_3 (2 to 20 g/L). The XRD spectra show that

Table 1. Weight loss of AZ31 Mg alloys, uncoated and coated by EPP method.

	Before	After	Weight loss
Uncoated	9.74386	9.570233	0.173623 (g)
Coated	8.1746	8.173767	0.000833 (g)

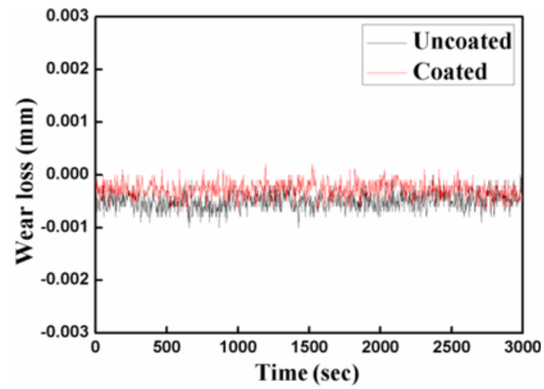

Fig. 4. Wear loss of AZ31 Mg alloys uncoated and coated by EPP in electrolyte of 12 g/L Na_2SiO_3.

the ceramic coatings were composed of the MgO and Mg_2SiO_4. The intensity ratio of Mg_2SiO_4 was found to increase with increasing Na_2SiO_3 concentration, whereas, the MgO intensity ratio was decreased.

The Vickers hardness values of EPP-treated AZ31 Mg alloys are depicted in Fig. 3. The micro-hardness of coatings increased with increasing Na_2SiO_3 concentration up to 12 g/L and then found to decrease with further increasing the concentration. Micro-hardness of coatings prepared in electrolyte containing 12 g/L Na_2SiO_3 was found to ~1080 Hv (10.6 GPa).

The wear-loss of coatings formed in electrolyte of 12 g/L Na_2SiO_3 was compared with the uncoated AZ31 Mg alloys. Coated specimen has better wear property and less weight loss than uncoated specimen. Because of the coated specimen (in 12 g/L Na_2SiO_3) has the denser, thicker and better Mg_2SiO_4 crystallinity than the coatings formed with the other Na_2SiO_3 concentrations.

4. CONCLUSIONS

Ceramic coatings are prepared on AZ31 Magnesium alloys by EPP method in NaOH-Na_2SiF_6 electrolyte with different concentration Na_2SiO_3. The coatings have pores distribution all over the surface. The coatings mainly consist of MgO and Mg_2SiO_4. Micro-hardness of coatings formed in electrolyte of 12 g/L Na_2SiO_3 was found to ~1080 Hv (10.6 GPa). It was also observed that the coated specimen has the better wear property and less weight loss than the uncoated specimen. Finally, we conclude that the mechanical properties of AZ31 magnesium alloy were improved through the EPP method.

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