

Microstructure and corrosion behavior of Mg–Nd coatings on AZ31 magnesium alloy produced by high-energy micro-arc alloying process

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Abstract

Mg–Nd coatings were prepared by high-energy micro-arc alloying (HEMAA) on AZ31 magnesium alloy. The coatings were treated with Ar shielding gas in ambient atmosphere. X-ray diffraction (XRD) results showed that the phases formed of Mg–Nd coatings were similar to that of Mg–Nd electrode. The corrosion behavior of the coated AZ31 in 3.5 wt% NaCl solutions was studied by simple immersion test and potentiodynamic polarization measurement. It was found that the corrosion resistance of coated alloy was higher than that of AZ31 substrate. The corrosion potential of Mg–Nd coatings was much positive to that of AZ31 substrate. Furthermore, the corrosion resistance is bad due to the presence of defects when treated with undesired processing parameters.

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1. Introduction

Magnesium alloys have higher strength, weight ratio than most light structural materials for transport and aerospace applications. A serious limitation for the potential use of magnesium alloys is their susceptibility to corrosion and wear [1]. One essential step to improve the surface properties such as wear, corrosion is surface modification by metallic coatings. Many studies related to the protection ability against corrosion of metal coatings carried out on magnesium alloys have been made in recent years [2,3].

Metallic coatings produced by high-energy micro-arc alloying (HEMAA) methods have many applications in the domains of hardfacing for their tribological and corrosion resistant properties [4–7]. The metal coatings via HEMA technologies seem to be a possibility to increase the corrosion resistance of magnesium alloys. In addition, there is not sufficient study about corrosion behavior of coatings for magnesium alloys.

Besides, rare-earth containing magnesium alloy has better corrosion resistance than those rare-earth free. Up to now, there has been almost no study on corrosion of rare-earth containing coatings on magnesium alloys.

In this study, Mg–Nd coating was prepared on AZ31 magnesium alloy using HEMA technique under different settings of processing parameter, and the corrosion behavior of the coated AZ31 alloy was then studied.

2. Experimental procedure

2.1. High-energy micro-arc alloying machine

In the present study, a commercial HEMA machine was used for applying Mg–Nd alloy onto the AZ31 surface. The two primary components of this machine are the power supply and the torch/applicator head. The power supply is to supply the instantaneous discharging energy for coating deposition [7–9]; the torch/applicator head, primarily for coating applications. The maximum output power of the HEMA machine is 1.5 kW (only can be output by 1500 W, 14% × 1500 W, 28% × 1500 W, 42% × 1500 W), with output of voltage 40 V, 60 V, 80 V and 100 V, continuously regulating frequency. The electrode is held on the torch/applicator head that rotates round its own axis during the work time.

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Table 1
Parameters used in the present experiment

Setting	Voltage (V)	Frequency (Hz)	Power (W)
1	60	100	420
2	80	250	630
3	100	525	1500

2.2. Material and coating methods

AZ31 magnesium alloy was chosen as substrate. The composition of AZ31 magnesium alloy is 2.5–3.5% Al, 0.5–1.5% Zn, 0.15–0.5% Mn, Mg is balance (in weight). The size of the samples is 10 mm × 10 mm × 4 mm. The surface to be coated is polished down to 800 grit emery paper and rinsed by acetone before treated. The electrode 3 mm in diameter consists of 89.9 wt% Mg and 10.1 wt% Nd alloy. The surface (10 mm × 10 mm) to be treated was traversed manually with a rotating anode with an approximate scan rate of 4 mm s⁻¹. The samples were treated for 3 min. Experimental parameter is shown in Table 1.

2.3. Electrochemical testing

Electrochemical polarization experiments were carried using a potentiostat PAR2263 system. Electrodes for this purpose were prepared by connecting a wire to one side of the sample, which was then covered with resin. The opposite surface of the specimen was exposed to the solution. The exposed area was about 1 cm². The AZ31 substrate was polished down to 800 grit SiC paper, and the Mg–Nd coated samples were the original surfaces followed by washing with distilled water and acetone. The test medium was 3.5 wt% NaCl saturated with Mg(OH)₂. Polarization measurements were carried out in a corrosion cell containing 200 ml of the solution using a standard three-electrode configuration: Ag/AgCl was used as reference and a platinum electrode as a counter. Specimens were immersed in the test solution and a polarization scan was carried out at a scan rate of 1.66 mV s⁻¹. The scan range was from -1.9 V to -1.1 V.

2.4. Immersion testing

For immersion test, the AZ31 substrate was polished down to 800 grit SiC paper, and the Mg–Nd coated samples were the original surfaces followed by washing with distilled water and acetone. The test solution was 3.5 wt% NaCl at pH 7. During the experiments, the temperature of the solution was kept at 25 ± 1 °C. Following the immersion tests, morphology of the tested samples was examined by scanning electron microscope (SEM).

2.5. Coating characterization

After the polishing and cleaning procedure, the cross-sections of the Mg–Nd coated samples were etched with picric acid solution and then observed in an optical microscope and in a scanning electron microscope with energy dispersive X-ray analysis. X-ray diffraction (XRD) technique was used for identifying the phase component of the Mg–Nd coatings, Mg–Nd electrode and AZ31 substrate.

3. Results and discussion

3.1. Surface and cross-section morphologies of the coatings

The surface morphologies of the Mg–Nd coatings on AZ31 alloy were shown in Fig. 1. Spattering pattern appears on the surface, which indicates the occurrence of spraying molten drops during coating process. The Mg–Nd coatings consist of countless single-spots. The similar results were reported by Wang et al. [8]. The cross-section morphology of the Mg–Nd coating on AZ31 alloy is illustrated in Fig. 2.

Because the thickness of the coating was not very regular, the average thickness may be estimated from the SEM micrographs. Fig. 2(a–c) illustrates the cross-section structure of the Mg–Nd

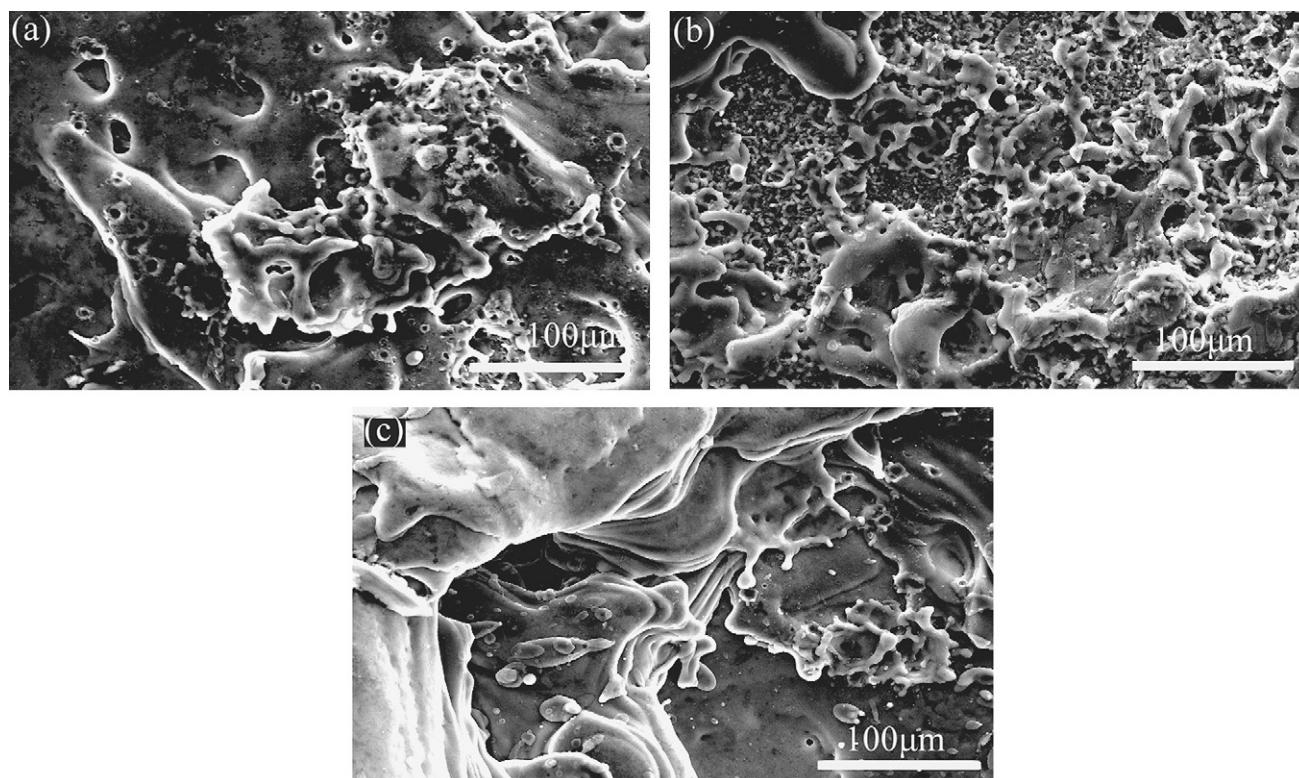


Fig. 1. Surface morphology of the alloying coating obtained under the parameters listed in Table 1. (a) setting 1, (b) setting 2 and (c) setting 3.

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