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EFFECTS OF ALUMINUM SPUTTERING ON THE CORROSION RESISTANCE OF AZ91 ALLOY

WPŁYW GLINU NANOSZONEGO METODĄ ROZPYLANIA JONOWEGO NA ODPORNOŚĆ STOPU AZ91 NA KOROZJĘ

The corrosion resistance of a Magnesium alloy is low and needs to be improved. This research aimed at corrosion-resistance improvement by supatterd deposition aluminium film, which is formed on the surface of AZ91 Magnesium-alloy. Corrosion resistance performed polarization curve measurement, was evaluated in quest of the corrosion rate using the Tafel extrapolation method, and conducted surface observation and EDS analysis by SEM. Although corrosion resistance is not improved only by film forming because of defects in film, corrosion resistance is improved by heat treatment for 3 hours by 553K after sputtering. In the case of heat treated at 623K and 673K for 3 hours, magnesium diffuses through the alminium film and reached the surface of the film. Thus, heat treatment at high temperature degrade the corrosion resistance of the film. The optimization of heat treatment after sputtering is important in this method.
Keywords: Magnesium alloy, corrosion, Aluminum, sputtering

Celem badań jest zwiększenie odporności na korozję stopu magnezu AZ91 poprzez naniesienie na jego powierzchnię warstwy glinu metodą rozpylania jonowego. Na podstawie pomiarów krzywej polaryzacji, oszacowano szybkości korozji metodą ekstrapolacji Tafela. Obserwacje morfologiczne oraz badania składu chemicznego wykonano metodą SEM-EDS. Nie stwierdzono poprawy odporności na korozję stopu z powodu defektów obecnych w warstwie. Jak wykazały badania, obróbka cieplna napylonej warstwy w 553 K przez 3 godz. wpłynęła na poprawę odporności korozyjnej. Gdy obróbka cieplna prowadzona była w temperaturach 623 K i 673 K przez 3 godz., magnez dyfundował poprzez warstwę glinu aż do powierzchni warstwy. Z tego względu obróbka cieplna prowadzona w wysokiej temperaturze obniża odporność warstwy na korozję. Ważnym aspektem tej metody jest zatem optymalizacja procesu obróbki cieplnej warstwy po rozpylaniu.

1. Introduction

Magnesium alloy is lightweight compared to other metals, has the advantage of high specific strength, and has excellent dimensional stability, vibration absorption, cutting resistance, and recyclability [1-3]. In various industries, the application of magnesium alloys is expanding. Therefore, it is expected as a lightweight material of the body for the purpose of improving fuel efficiency of transportation equipment-related fields, including particularly automotive. However, practical metal, magnesium alloy shows a lower potential than other metal materials in the active ionization tendency basis. Therefore, improvement of corrosion resistance is essential in order to utilize the superior features of magnesium [4]. In order to improve the corrosion resistance of the Mg alloy, AZ91 alloy coated with deposited Al film on the surface was investigated to evaluate the effect on the electrochemical properties in this study.

2. Experimental

2.1. Sample preparation

Deposition was using the facing target magnetron sputtering apparatus [Osaka vacuum, FTS-R2]. A1070 aluminum alloy was used as target in the form of 160 mm×100 mm×10 mm. AZ91 was used as the substrate, was wet-polished as a pretreatment, and then mirror-finished by buffing with a 1μm alumina, it cleaned by 10 minutes each in the order of acetone, ethanol and propanol. Sputtering was carried out in a vacuum of 0.24 Pa. During deposition, radio frequency power was set at 980 W and substrate was kept at room temperature. After the deposition, each sample was heat treated for 3 hours at 553K, 623K, and 673K, in Ar atmosphere. These samples were observed microstructure by using the SEM [JEOL, JSM-5900LV]. The chemical composition analysis was used the SEM-EDS, in the crystal structure analysis of the membrane was used X-ray diffraction apparatus [Philips, X'pert system].

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2.2. Polarization curves measurement

The AZ91 alloy with deposited Al film was measured polarization curves to examine the basic electrochemical properties of it. Polarization curves measurement was used potentiostat [Bio logic, SP150]. Polarization curves measurement was carried out using a typical three-electrode method. Each electrode was used the Ag / AgCl (3.33 kmol·m-3KCl) electrode as a reference electrode, a Pt electrode as a counter electrode and the sample electrode reaction area of 1.0×10-4 m2 in the working electrode, respectively. Polarization curves measurement was carried out in 3.5mass% NaCl aqueous solution(pH = 5.35) as corrosion solution, and electrochemical cell that held 298 K was degassed thoroughly using a high-purity nitrogen gas. Scanning of potential was carried from 1.6 V to 0.0 V at a scan rate of 0.5×10-3 V·s-1, and recorded the logarithm of the current density and the potential. The corrosion rate of each samples were determined based on the result of the polarization curve measurement. Further, to obtain stable results, scanning for potential was started after pre immersed for 30 minutes.

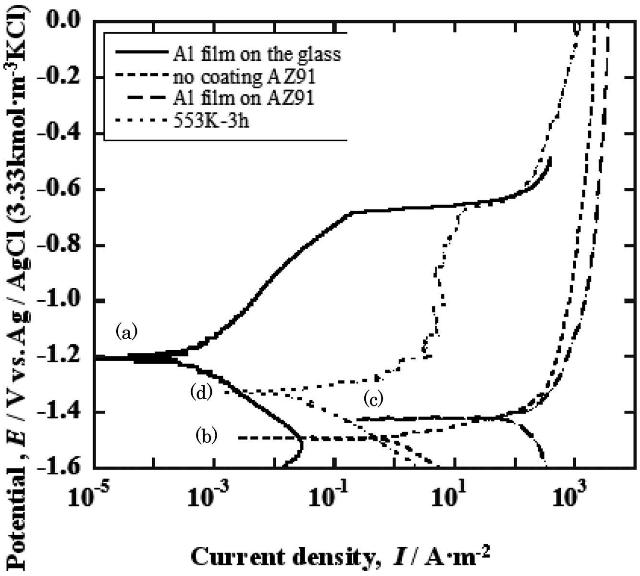

Fig. 1. Polarization curve of the Al film on the glass, no coating AZ91, coated sample and sample were annealed in argon after deposition measured in 3.5mass% NaCl solution at 298K; Al film on grass substrate (a), AZ91 magnesium alloy substrate (b), Al coated AZ91 alloy (c), and aluminum coated AZ91 alloy annealed at 553K for 10.8 ks (d)

3. Results and discussion

Figure 1 shows results of the polarization curve measurements.; Al film on glass substrate Fig. 1(a), AZ91 magnesium alloy substrate Fig. 1(b), Al coated AZ91 alloy Fig. 1(c), and aluminum coated AZ91 alloy annealed at 553 K for 10.8 ks in Ar atmosphere Fig. 1(d). From the results of the polarization curve measurement, corrosion potential (E_{corr}) of each samples were -1.20, -1.50, -1.42 and -1.32V, respectively. The corrosion current (I_{corr}) of each samples were determined using the Tafel extrapolation method, it became 3.59×10^{-4}, 0.94, 99.4 and 2.70×10^{-2} A/m^2, respectively. E_{corr} or I_{corr} in Al film on glass substrate is the target value of the our study. In comparison with Fig. 1(b), E_{corr} and I_{corr} of Fig. 1(c) is higher. It can be considered that Al film promoted the cathode reaction. Compared Fig. 1(c) with Fig. 1(d), the corrosion potential is further increased, by annealing for 10.8ks at 553 K after deposition. The corrosion rate is significantly reduced, the corrosion resistance is improved. It can be considered that the corrosion rate is reduced by being inhibited the anodec reaction by Al rich layer that produced in Al film / substrate interface due to do thermal diffusion.

Figure. 2 shows the influence of annealed temperature on atomic concentration of magnesium and aluminum in surface of samples. Al concentration decrease or Mg concentration increased with annealing temperature linearly. The sample annealed for 10.8 ks at 553 K, was not recognized change of chemical concentration of surface layer and morphology of it. From these result, the surface of the sample annealed for 10.8 ks at 553 K have remained Al layer. Al rich intermediate layer can be produced on Al deposition / substrate by annealing. Intermediate layer improved corrosion resistance by the adhesion of Al film and substrate.

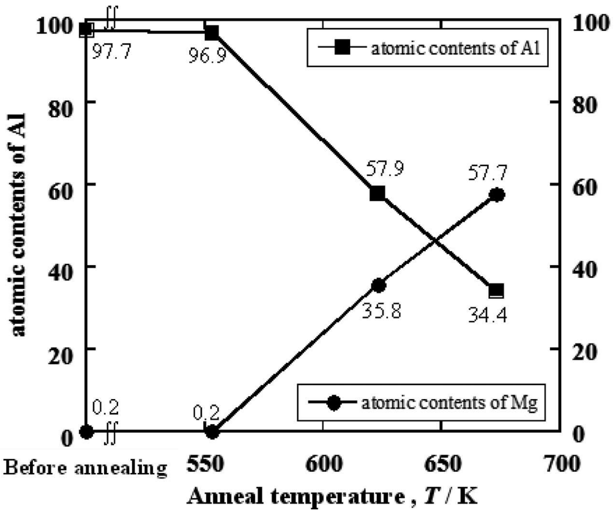

Fig. 2. Influence of annealed temperature on atomic percent magnesium and aluminum in surface of samples were annealed for 10.8 ks under argon after deposition

4. Conclusions

The corrosion resistance was not improved only the aluminum deposition, but it was improved by performing heat treatment after deposition 553K at 10.8 ks.

By performing heat treatment for 10.8 ks at higher temperatures, the corrosion resistance is deteriorated by the diffusion of magnesium to the surface. Al film is effective in improving corrosion resistance, but must be set to an appropriate value, time and the heat treatment temperature in order to improve the corrosion resistance.

REFERENCES

[1] ZHANG Jin, YANG Dong-hua, OU Xin-bing, “Microstructures and properties of aluminum film and its effect on corrosion resistance of AZ31B substrate”, Transactions of Nonferrous Metals Society of China **18**, 312-317 (2008).

[2] Yo Kojima, Tadao Ito, “Technologies & Applications of Magnesium Alloys” 14-15 (2006).

[3] Japan Magnesium Association, ”Magnesium metal material series to take advantage of in the field” 29-33 (2009).

[4] Hikmet Altun, Sadri Sen, “The effect of DC magnetron sputtering AlN coatings on the corrosion behaviour of magnesium alloys”, Surface & Coatings Technology **197**, 193-200 (2005).

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