Surface & Coatings Technology 202 (2008) 5603–5606

Contents lists available at ScienceDirect

Surface & Coatings Technology

journal homepage: www.elsevier.com/locate/surfcoat

Influence of interlayers on corrosion resistance of ion-plated Mg thin films

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ARTICLE INFO

Available online 21 June 2008

Keywords:
Ion-plated Mg film
Corrosion resistance
Interlayers

ABSTRACT

It is well known that the film formed by PVD process has different characteristics depending on the process conditions. In this experiment, therefore, the corrosion characteristic of Mg film prepared by PVD method onto electroplated Zn, Al and Sn steel substrates at different Ar gas pressure conditions is studied. From the experimental results, the corrosion resistance of Mg film is obviously correlated with the morphology of film and a formation of galvanic couple with interlayer. The film of granular structure which deposited in condition of high gas pressure has certainly good corrosion resistance. Especially Mg film on Zn interlayer, a sacrificial anode protection to substrate is continuously sustained by relatively low galvanic current in galvanic couple between deposited Mg film and Zn interlayer during immersion in 3% NaCl solution.

1. Introduction

The conventional coating processes as hot dip and electrochemical deposition coating on steel substrates are commonly used to enhance the hardness, decoration as well as corrosion resistance for increasing its life-time. However, although conventional processes have relatively low cost and high deposition rate, these processes have been constantly pointed out to entail fundamental environment pollution problems. For this reason, PVD method which produces the environmentally friendly film is beginning to receive great attention as an alternative to the electroplating and electroless plating [1]. Accordingly corrosion resistance film by PVD method has been tried, however some of them concluded that the PVD coatings (as TiN, CrN, Cu, Au, etc.) showed a limited corrosion resistance due to their intrinsic porosity which locally expose the portion of substrate. Also, deposition of thick coating film which is enough to isolate from corrosion environment usually resulted in high internal stress and low adhesion [2–6]. Therefore, coating film for corrosion protection needs to have a good insulation from corrosion environment with thin thickness.

Mg coating film by PVD method can support sacrificial protection to substrate if damage occurs to the coating and be effective in isolating the substrate from the corrosion environment by producing protective corrosion products as MgO or $Mg(OH)_2$ [7].

In this experiment, therefore, the corrosion characteristic of Mg film prepared by PVD method onto electroplated Zn, Al and Sn steel substrates at different Ar gas pressure conditions is studied.

2. Experimental procedure

Mg thin films were deposited by the thermo-electron activated ion-plating system [Fig. 1]. Substrates were electroplated Zn, Al and Sn steel. Evaporation material was magnesium with a purity of 99.99%. Prior to deposition, all of the specimens are cleaned with trichloroethylene in an ultrasonic bath and further cleaned by argon ion-bombardment at 5×10^{-1} Torr (bias voltage: −500 V). The deposition is then carried out by supplying argon gas and applying −200 V of substrate bias for 20 min as shown in Table 1.

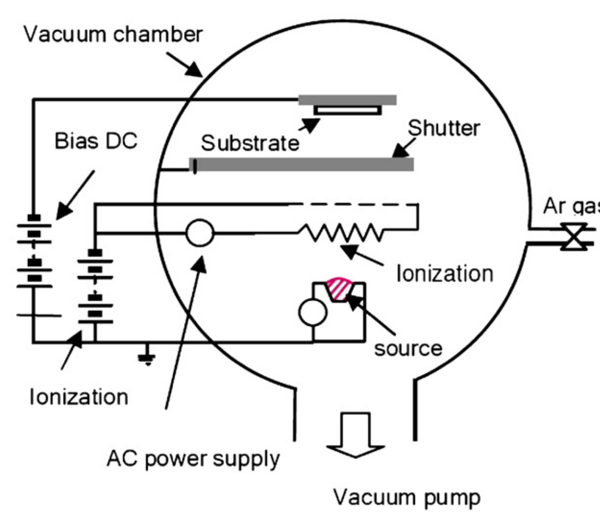

Fig. 1. Schematic diagram of ion-plating apparatus.

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doi:10.1016/j.surfcoat.2008.06.150

Table 1
Deposition conditions

Substrate (electroplated steel, 7–8 μm)	Argon gas pressure	Bias voltage
Zn interlayer	5×10^{-1} Torr	−200 V
Al interlayer	5×10^{-2} Torr	
Sn interlayer	5×10^{-4} Torr	
Evaporation metal	99.99% magnesium	

After deposition, the top surface and cross-section of the magnesium film was observed by scanning electron microscopy (SEM: JSM-540, JEOL, Japan). X-ray diffraction was performed by D/Max-2000 diffractometer (Rigaku Co., Japan) with Cu Kα radiation to obtain the diffraction peak of Mg thin film. For evaluation of corrosion resistance, anodic polarization measurements were carried out by Potentio-stat of CMS 100 system (Gamry Ins., America). Prior to the polarization measurement, open-circuit potential ($E_{\text{open-circuit}}$) of specimens was measured for 20 min. And the polarization scan was then begun at $E_{\text{open-circuit}}$ and scanned to anodic polarization at a scan rate of 1 mV/s in 3% NaCl solution.

3. Experimental results and discussion

3.1. Morphology and crystal orientation of magnesium film

Fig. 2 shows the top surface and cross cross-section of Mg films which are deposited by ion-plating method. As gas pressure increases, regardless of interlayer, it can be seen that the morphologies of Mg thin film are changed from columnar structure into granular structure with dense and homogeneous morphologies. It is considered that a nucleus of films is becoming relatively faster than a nucleus growth by the effect of absorption and occlusion according to the increase of argon gas pressure.

X-ray diffraction patterns as a function of argon gas pressure at different interlayers for the deposited Mg film are shown in Fig. 3. As can be seen, two main Bragg diffraction peaks are clearly observed at 2θ=34.39° and 36.62°, corresponding to (002) and (101) plane of magnesium. The diffraction peak of Mg film has very low relative intensity which indicates the small grain size of Mg film according to the increase of argon gas pressure. Also, the preferred crystal orientations of Mg film which deposited on the Zn and Sn interlayer substrate are heavily correlated with the argon gas pressure [Fig. 3(a) and (c)]. And X-ray diffraction patterns of Mg film which was formed on the Al interlayer exhibited (002) preferred orientation at all deposition conditions as shown in Fig. 3(b). The formation of Mg film with different crystal orientation at the same process conditions is

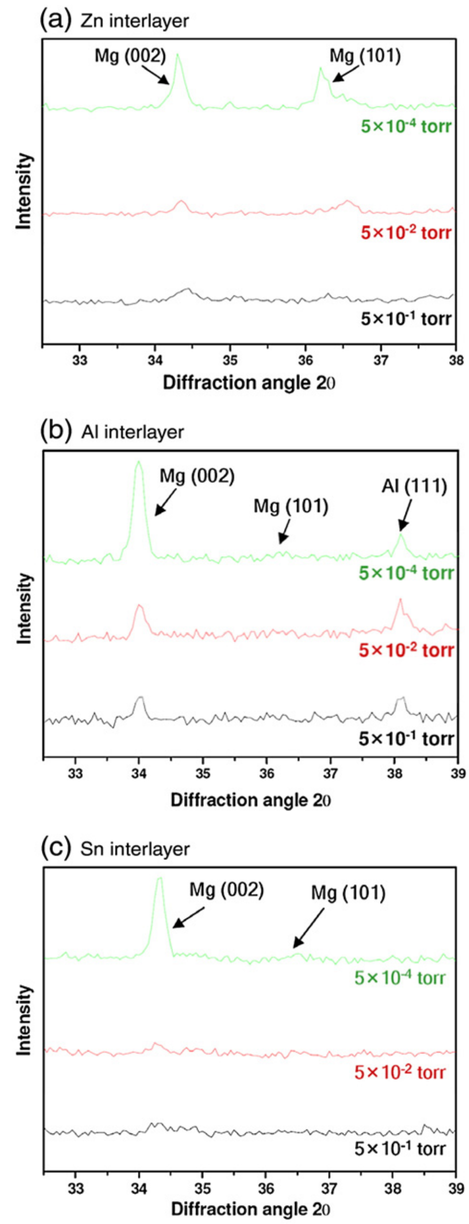

Fig. 3. X-ray diffraction patterns of Mg films deposited on different interlayers. (a) Zn interlayer. (b) Al interlayer. (c) Sn interlayer.

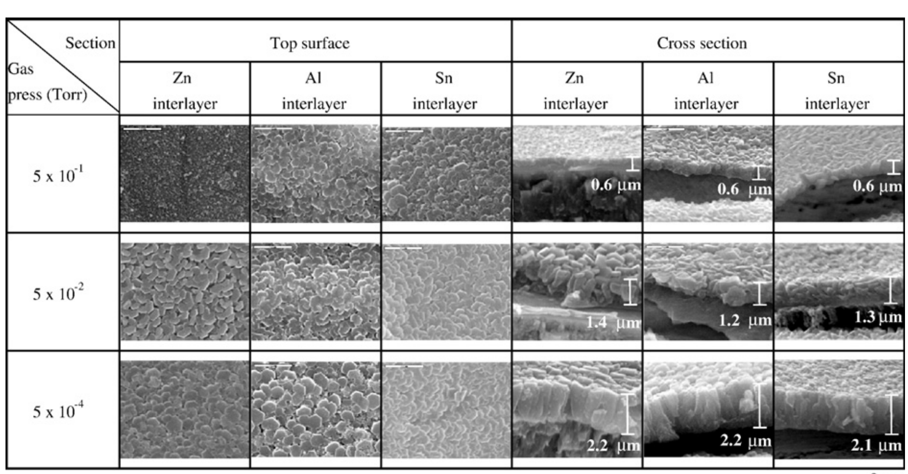

Fig. 2. SEM photographs of Mg films (−200 V bias voltage).