Atmospheric Pressure Plasma Deposition of Corrosion Protective Coatings on Magnesium Alloys

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Abstract: Atmospheric pressure plasma-based coating processes were applied on Mg alloy substrates for corrosion and wear protection. The siloxane-based deposited coatings were uniform with thickness ranging between 250 nm and 1 µm, depending on the plasma process conditions. Corrosion studies showed that the plasma-deposited silane coatings were effective in mitigating corrosion.

1. Introduction

Magnesium alloys are highly valued in the automotive industry due to their lightweight, strength and durability, that contribute to improved fuel efficiency and lower greenhouse gas emissions. However, they are susceptible to corrosion, particularly galvanic corrosion by more noble materials. Exposure to chloride ions, humidity, and other aggressive media can accelerate corrosion. Common mitigation strategies involve surface treatments like ion implantation, laser annealing, and protective coatings that can enhance the corrosion resistance of Mg alloys [1]. In this work, the plasma-assisted, large area deposition of dense, organosilicon coatings on AM60 and AZ91D Mg alloys using atmospheric pressure plasma jets is presented.

2. Methods

A two-step plasma process was applied on Mg alloy coupons. First a N_2-based plasma (RD1004, Plasmatreat USA, Inc) was applied to clean and prepare the surfaces for the subsequent deposition process which was carried out using an atmospheric pressure-based plasma jet system (PlasmaPlus®, PFW10-PAD, Plasmatreat, USA, Inc). For the deposition process, clean dry air was used as the plasma generating gas at a flow rate of 33-40 lt/min, along with 2 types of siloxane precursors. The plasma jets were moved over the substrates at constant speed, ranging from 50-200 mm/s, with the assistance of a robotic system (Janome, model 3403).

The electrochemical characterization involved immersion of the Mg alloy substrates in a 3.5 wt.% NaCl solution. Multi-scale image characterization and chemical analysis was performed using scanning electron microscopy (SEM, TESCAN) equipped with energy dispersive X-ray spectrometry (EDS, Oxford Instruments) and scanning transmission electron microscopy system.

3. Results and Discussion

Mg alloy samples produced under various coating process conditions were studied. The speed and gap of the plasma jet moving over the substrates, as well as the flow rate of the precursor were found to be critical parameters of the process. As an example, the Si/C and O/C values obtained from electron energy loss spectroscopy (EELS) for 2 coating processes, P01 and P08, were found to vary from 5.25 and 6 (P01) to 2.65 and 2.1 (P08), respectively. This difference in the coating chemical composition is primarily due to the higher flow rate of the siloxane precursor that was used in P01 compared to P08 [2]. More importantly, the elemental composition remains relatively constant throughout the entire depth of the coating, as demonstrated in Figure 1.

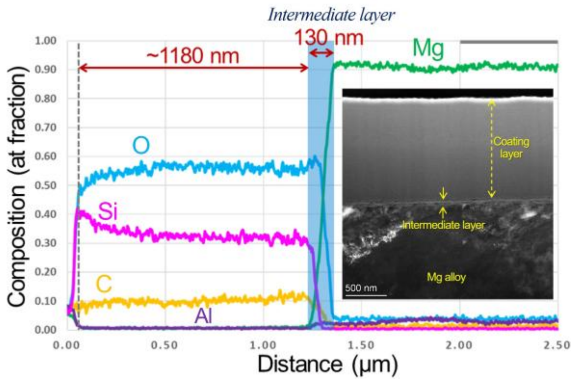

Fig. 1. Surface characterization of plasma-deposited organosilicon coating on a AM60 Mg alloy substrate: STEM-EDS depth profile analysis (main graph), and cross-sectional SEM image (inset)

Additionally, the results from the electrochemical characterization indicate that both P01 and P08 coatings have reduced corrosion rates at natural corrosion potentials and cathodic/anodic currents under potentiodynamic polarizations for AZ91D Mg alloy samples. More information correlating the plasma process parameters to the elemental composition, thickness and corrosion resistance will be presented.

4. Conclusion

The results indicate that plasma-coated organosilicon layers can significantly reduce corrosion and increase the wear resistance of Mg alloy materials.

References

[1] H. Hu et al., Magnesium Alloys, F. Czerwinski, IntechOpen, Ch.**3**, (2014).
[2] J. Jun et al., J. Coat. Technol. Res., **21**, 1097-1111 (2024).