

Corrosion inhibition mechanisms of composite corrosion inhibitors for magnesium alloy

Youmin QIU^{1,2}, Junjie YANG^{1,3}, Qiwei WANG¹, Wei LI¹

(1. Institute of Advanced Wear & Corrosion Resistant and Functional Materials, Jinan University, Guangzhou 510632, China;

2. Institute of Surface Science, Helmholtz-Zentrum Hereon (Hereon), Geesthacht 21502, Germany;

3. Shaoguan Research Institute of Jinan University, Shaoguan 512027, China;)

Abstract The use of corrosion inhibitors is a simple and easy to implement to reduce the corrosion rate of magnesium (Mg) alloys with extending their service life of the workpiece protection measures. However, the corrosion inhibitors for Mg alloys are still faced with the problem of limited quantity and the efficiency is difficult to meet the industrial requirements. Mixing two or more chemicals with synergistic effect can effectively improve the corrosion inhibition efficiency of corrosion inhibitors. In this study, the image processing-based high-throughput method was used to screen the combination of compounded corrosion inhibitors (i.e., NaF+DMA and NaF+ATT) with efficient corrosion inhibition capability. The results showed that high corrosion inhibition efficiencies of 94.1%@72 h and 95.8%@24 h were obtained when fluoride ions were compounded with malic acid (DMA) and 3-amino-5-mercapto-1,2,4-triazole (ATT) at 50 mM:50 mM and 50 mM:5 mM, respectively. The compounding of NaF with DMA was achieved by forming a dense precipitation layer on the surface consisting of spherical NaMgF₃ particles. The corrosion inhibition effect is achieved by forming a dense precipitation layer consisting of spherical NaMgF₃ particles on the surface, while DMA can isolate the surface fluoride ions to reduce the ratio of [F⁻:Mg²⁺] at the metal/solution interface. Such a behavior of fluoride can make the shape transformation of NaMgF₃ from cubic into spherical. However, DMA can be involved in the nucleation and growth of NaMgF₃ particles, and then increase the nucleation precursor of NaMgF₃ particles through the formation of Mg(DMA) complex. As a result, smaller size and higher number of NaMgF₃ particles were obtained with improving the

corrosion resistance. In contrast, ATT was transformed from physical adsorption to mixed physical-chemical adsorption in the solution containing fluoride ions, and the adsorption energy was significantly enhanced in the presence of fluoride ions. Fluoride ions reduced the excess negative charge on the surface of the Mg alloy, promoting the adsorption of deprotonated ATT molecules on the surface, while the loose $Mg(OH)_2$ could be stably transformed to $Mg(OH)_2 \cdot xF_x$ under the protection of the adsorption layer of ATT. Then products provide a stable adsorption matrix for ATT, thus realizing the synergistic corrosion inhibition effect that adsorption and precipitation promote each other.

Keywords: Magnesium alloy; Composite inhibitors; Fluorion; Synergistic effect; Corrosion inhibition mechanism;