



A novel time-lapse microscopy technique to study the corrosion mechanisms and effects of phosphate inhibitor during the corrosion of a zinc-magnesium-aluminium alloy coating

**Nathan COOZE¹, James SULLIVAN¹, Thomas LEWIS¹, Callum GALLAGHER¹,
Dominique THIERRY², Tomas PROSEK²**

¹ *Swansea University, United Kingdom*

² *Institut de la Corrosion, France*

The drive to develop new zinc-magnesium-aluminium alloys (ZMA) is concurrent with the need to find replacements for chromate corrosion inhibitors as governed by environmental REACH legislation. Therefore, an understanding of the behaviour of these ZMA alloys protected by alternative inhibitor systems is of significant interest within the galvanising industry. Phosphate ions have been shown to work effectively as a corrosion inhibitor on galvanised steels in previous studies [1-3] showing that phosphate ions in solution react with metal cations released from the metals surface and precipitate as a film that acts as a barrier in anodic areas.

The microstructural corrosion mechanisms of a Zn-2wt.%Mg -2wt.%Al alloy coating in 1wt.% NaCl at pH 7 were initially observed without inhibitor additions using in-situ time-lapse optical microscopy. Preferential corrosion of the MgZn₂ lamellae within the eutectic phases was observed followed by subsequent dissolution of Zn-rich phases. The effects of different amounts of Na₃PO₄ additions in solution, namely 1x10⁻⁴ mol.dm⁻³, 1x10⁻³ mol.dm⁻³ and 1x10⁻² mol.dm⁻³, for this system were studied. Corrosion was initiated by immersing the sample in 1wt.% NaCl and sodium phosphate inhibited 1wt.% NaCl was introduced to the system after a prescribed time, using in-situ time-lapse microscopy to monitor the subsequent effects. It was found that the phosphate inhibitor additions had a dramatic effect on the observed corrosion behaviour of the samples, particularly at concentrations of 1x10⁻² mol.dm⁻³ and 1x10⁻³ mol.dm⁻³.

Rapid precipitation of filamentous phosphate was observed in 1wt.% NaCl with additions of 1x10⁻² mol.dm⁻³ Na₃PO₄ and it is postulated that these filaments nucleate and grow due to supersaturation effects. In 1wt.% NaCl with additions of 1x10⁻³ mol.dm⁻³ Na₃PO₄ phosphate appeared to act as an anodic inhibitor with phosphate precipitates seen in the anodic region. A similar phenomenon was seen for samples immersed in 1wt.% NaCl at 1x10⁻⁴ mol.dm⁻³ with Na₃PO₄ additions but with phosphate precipitation occurring at a slower rate. Electrochemical measurements showed that as inhibitor concentration was increased, a region of passivity was produced with this extending for over-potentials of 40 mV for a phosphate concentration of 1x10⁻² mol.dm⁻³ Na₃PO₄. Scanning vibrating electrode technique (SVET) was used to estimate mass loss and showed a decrease in mass loss for increasing concentrations of phosphate inhibitor. These data therefore support the findings of the time-lapse microscopy studies, that indeed phosphate was acting predominantly as an anodic inhibitor in this system.

References

- [1] I. M. Zin, S. B. Lyon, V. I. Pokhmurskii. Corrosion Science. 2003, 45, 777.
- [2] A. M. Simões, J. Torres, R. Picciochi, J. C. S. Fernandes. Electrochimica Acta. 2009, 54, 3857.
- [3] S. M. Powell, H. N. McMurray, D. A. Worsley. Corrosion. 1999, 55, 1040.