Study of zirconia and silica-zirconia-epoxy sol-gel coatings for corrosion protection of EN AW 6063 aluminium alloy

I. Rute Fontinha[a], Wilson Gouveia[b], Maria José Lourenço[b,c], M. Manuela Salta[a] and Mário G. S Ferreira[d]*

[a]LNEC – Laboratório Nacional de Engenharia Civil, Lisboa, Portugal, [b]FC-UL – Faculdade de Ciências da Universidade de Lisboa, Portugal, [c]CCMM - Centro de Ciências Moleculares e Materiais, Faculdade de Ciências da Universidade de Lisboa, Portugal [d]CICECO- Centro de Investigação em Materiais Cerâmicos e Compósitos, Universidade de Aveiro, Portugal

*rfontinha@lnec.pt

Coating an aluminium alloy in building and automotive industries requires its surface pre-treatment to promote adherence of the organic coating. Chromate based chemical conversion layers (CCC) have been extensively used for that purpose since they not only provide very good adhesion of organic coatings, but also afford corrosion protection, both by barrier and self-healing effect. However, the use of these surface treatments has been under severe restrictions in the European Community due to Cr (VI) toxicity and carcinogenic effects. Within building industry, several "green" alternative inorganic treatments are already being applied, but they lack the anticorrosive action of the Cr(VI) compounds. Coating via the sol-gel process has been pointed out as a promising environmentally friendly alternative to chromate pre-treatments. This type of coatings, namely the organic-inorganic hybrid sol-gel silane based ones provide corrosion protection by barrier effect and when corrosion inhibitors are incorporated in their structure active protection is conferred as well. The sol-gel coating is also able to promote adherence between the metallic substrate and an organic top layer.

In this work, several organic-inorganic hybrid (IOH) sol-gel coatings with different organic content were synthesized from glycidoxypropyltrimethoxysilane (GPTMS) and zirconium n-propoxide (TPOZ) precursors by the sol-gel process. Cerium nitrate was added during synthesis to be incorporated in the final coating and act as corrosion inhibitor. The synthesized OIH coatings were applied on EN AW-6063 alloy by dip-coating. The corrosion protection performance of coatings was evaluated in chloride medium by means of Electrochemical Impedance Spectroscopy (EIS) and by Salt Spray Test (NSS). A solely inorganic zirconium based sol-gel coating was also prepared and tested for comparison. The chemical composition with depth was analysed by means of Glow Discharge Optical Emission Spectroscopy (GDOES) and the thickness of coatings was estimated based on elemental depth profiles. Finally the aluminium alloy coated samples were bent to evaluate coatings adhesion to the substrate. The morphology of the aluminium coated samples after corrosion and deformation tests was observed by scanning electron microscopy (SEM-EDS).

Electrochemical measurements provided evidence that the hybrid sol-gel coatings are much more corrosion protective than the solely inorganic ones. Additionally, it was observed that an increase in the organic content by the introduction of the epoxysilane in the coating formulation improves its corrosion resistance, but above a certain limit is detrimental to coating adherence, as shown by the bending test. The Salt Spray test confirmed EIS ranking of coatings' corrosion resistance. GDOES elemental profiling revealed that sol-gel coatings thickness increases with organic content. However, this had not necessary implied a better corrosion behaviour. The best corrosion performance was achieved by the hybrid coating with a Zr/Si molar ratio of 0.26.