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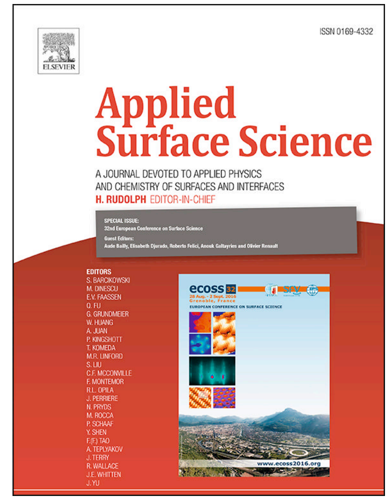

Full Length Article

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Nano-scale mechanical and wear properties of a waterborne hydroxyacrylic-melamine anti-corrosion coating

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Abstract

Corrosion protection is commonly achieved by applying a thin polymer coating on the metal surface. Many studies have been devoted to local events occurring at the metal surface leading to local or general corrosion. In contrast, changes occurring in the organic coating after exposure to corrosive conditions are much less studied. In this article we outline how changes in the coating itself due to curing conditions, environmental and erosion effects can be investigated at the nanometer scale, and discuss how such changes would affect its corrosion protection performance. We focus on a waterborne hydroxyacrylic-melamine coating, showing high corrosion protection performance for carbon steel during long-term (≈ 35 days) exposure to 0.1 M NaCl solution. The effect of curing time on the conversion of the crosslinking reaction within the coating was evaluated by fourier transform infrared spectroscopy (FTIR); the wetting properties of the cured films were investigated by contact angle measurement, and the corrosion resistance was studied by electrochemical impedance spectroscopy (EIS). In particular, coating nanomechanical and wear properties before and after exposure to 0.1 M NaCl, were evaluated by atomic force microscopy (AFM). Fiber-like surface features were observed after exposure, which are suggested to arise due to diffusion of monomers or low molecular weight polymers to the surface. This may give rise to local weakening of the coating, leading to local corrosion after even longer exposure times. We also find a direct correlation between the stick-slip spacing during shearing and plastic deformation induced in the surface layer, giving rise to topographical ripple structures on the nanometer length scale.

Key words

Waterborne anti-corrosive coating; Electrochemical impedance spectroscopy; Nanomechanical property; Nanowear; Fast fourier transform analysis

1. Introduction

Carbon steel is a widely used construction material due to favourable mechanical properties, machinability and low cost. However, corrosion of carbon steel, occurring in almost all practical environments, limits its life expectancy in structures. In fact, corrosion in general constitutes a large economical burden, consuming over 3% of the World's GDP as reported by the World Corrosion Organization in 2010 [1]. Therefore, corrosion protection is of significant importance from both economical and structural integrity perspectives. The use of organic coatings, which consists of a complex mixture of binder, pigments and fillers, additives and solvents, is a common and often effective approach for corrosion protection, where its primary function is to separate the base metal from the corrosive species. A barrier coating protects metal materials against corrosion by retarding diffusion of corrosive species, such as water, oxygen, chloride ions and sulphate ions, through the coating. In addition, a barrier coating also provides corrosion protection by retarding the corrosion reaction by inhibiting the charge transfer between local anodic and cathodic sites. Barrier coatings are widely applied in the field of infrastructure facilities, vehicles, packaging industries and marine related applications [2]. Coatings may also contain active pigments and inhibitors that provide protection when there is a damage to the coating layer, giving rise to self-healing effects [3].

However, organic coatings are rather easily damaged under mechanical load. For this reason, even initially effective barrier coatings will not provide sufficient corrosion protection when suffering from wear, crack formation or stress fractures. Thus, a coating with good mechanical properties is the prerequisite of good corrosion protection performance. The related mechanical properties such as elastic modulus, wear resistance, and friction properties are all of great significance for the sustainability of such coatings. Some classical techniques like microindentation, nanoindentation and pin-on-disc can provide valuable mechanical data, but they cannot provide local information on the nm-length scale, which is of importance for understanding property variations locally on a surface and initiation of wear. In order to gain such information a very small probe is needed as offered by scanning