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Influence of the oxide/coating interface on the adhesion and delamination of organic coatings.

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Abstract

Covering steel substrates by organic films is probably the most popular way of corrosion protection, and this because organic coatings can be easily applied and adjusted to give the steel surface additionally the desired optical and mechanical properties. In order to replace chromium-based conversion coatings, nowadays steel substrates are covered by ultrathin (non-)ferrous oxide films which should provide strong stable bonds to polymer topcoat(s). In particular the achievement of high adhesion strength, even in hostile environments, is an omnipresent engineering problem for these kind of multilayer systems. Furthermore, they should withstand severe forming operations and long-term exposure to corrosive environments.

The aim of this work is to come to a better understanding how the properties of the interfacial oxide film affect adhesion and delamination of organic coatings. To attain this goal, polished steel substrates are treated in order to form oxide films having different surface and bulk properties. First, the oxide properties, which might be of influence upon adhesion and delamination, are characterised by several techniques, e.g. ellipsometry (oxide thickness), X-ray photoelectron spectroscopy (surface hydroxyls and Fe^{2+}/Fe^{3+} ratio), contact angle measurements (surface energy) and electrochemical impedance spectroscopy (doping concentration, flatband potential, oxide resistance). At a later stage, these properties are linked to possible variations in adhesive behaviour of organic coatings and to possible fluctuations towards de-adhesion and instability of oxide/polymer interfaces.

First, adhesion of some industrially relevant organic coatings is simulated by studying the adsorption of several model compounds having the same organic functionalities as the respective coatings. By means of X-ray photoelectron spectroscopy and infrared reflection absorption spectroscopy, the binding mechanism and amount of adsorbants is investigated as a function of the physicochemical condition of the oxide surfaces. This study shows that the density of oxide surface hydroxyls is the most crucial parameter regarding molecular adsorption. Additionally, Volta potential shifts are measured by scanning Kelvin probe to examine the interface dipole which is formed between the oxide surface and the adsorbing molecules as a result of physical or chemical bonding. The orientation and amplitude of the interface dipole moment provide information about the interaction type and charge transfer occurring at the moment of adsorption. Second, the adhesion of industrial coatings which are applied on the differently treated steel substrates is investigated. Their adhesion strength is measured and linked to the oxide properties and to the Volta potential shifts which are induced by coating application. The potential shifts are determined by the potential drop at the oxide/polymer interface. The last part describes the coating delamination in corrosive environment. Scanning Kelvin probe is used to track the delamination progress and to study the condition of the oxide/polymer interface. Special attention is drawn to the role of the interface in the cathodic delamination process as the interface controls the delamination velocity of the organic coating in the conditions applied here. Cation transport along the interface is the rate-determining step and is therefore studied as a function of the oxide surface properties, along with the adhesion strength of the coating.