Anti-corrosion hybrid coatings based on epoxy–silica nano-composites: Toward relationship between the morphology and EIS data

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This work reports on design and manufacture of organic–inorganic hybrid coatings based on diglycidyl ether of bisphenol A (DGEBA) epoxy resin pursuing hydrolyzation of tetraethoxysilane (TEOS) through a sol–gel process. The resulting hybrid materials were cured to be used as potential anticorrosive coatings. The assigned materials were modified molecules made of DGEBA and 3-aminopropyl triethoxysilane (APTES), in which the molar ratio of epoxide group of DGEBA to NH− of APTES varied in the order of 2:1, 4:1, 8:1 and 16:1. In the next stage, the APTES-modified DGEBA precursors were added to different amounts of pre-hydrolyzed TEOS, i.e. 7.5, 12.5 and 17.5 wt%, as inorganic part of the resulting hybrid. The mixtures were subsequently cured at room temperature by a cycloaliphatic amine based curing agent to yield transparent epoxy–silica hybrid coatings. Microstructure assessment of the hybrid materials, before and after curing, was performed using FTIR and 29Si NMR spectroscopies. The morphology of the epoxy–silica hybrid coatings has also been studied by scanning electron microscopy (SEM). The anticorrosive measurements on the resultant coatings were conducted based on electrochemical impedance spectroscopy (EIS). The mechanical properties evaluation such as micro-hardness measurements and pull-off adhesion tests of the cured samples were also carried out. The thermal properties of the cured hybrid coatings were evaluated using thermogravimetric analysis (TGA). The results showed that the concentration of APTES and pre-hydrolyzed TEOS play an important role in determining the morphology as well as the mechanical and thermal properties of coatings. The EIS results corresponding to these effects reaffirmed that the corrosion resistance of the hybrid coatings improved with increasing the inorganic phase content.

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1. Introduction

Corrosion is a phenomenon through which a metal deteriorates as a consequence of its interaction with the surrounding environment that helps for an electrochemical reaction via oxidation. To protect or slow down the corrosion process, metals are often coated to yield a protective barrier against corrosive environment [1–4]. In recent years, explore and development of hybrid coatings grabbed the attention of many researchers and engineers providing them the opportunity of designing appropriate primers or in situ pretreatment coating systems for the protection of metal substrates with outstanding characteristics compared to their organic counterparts [5–11]. These materials, denoted as organic–inorganic hybrids, typically contain co-continuous domains having dimensions ranging in 5–100 nm [12–17]. In this regard, a wide variety of applications were demonstrated for multifarious fields, e.g. rubbers, plastics, sealants, fibers, optical materials, medicals, and high thermal resistance materials [18–26].

The hybrid coatings are generally prepared by low-temperature sol–gel processes through in situ hydrolysis followed by condensation of organometallic precursors like silicates, titanates and aluminates, in an organic matrix [27]. Careful selection of a hybrid coating allows combining the desirable properties of organic part of system, i.e. toughness and elasticity with those of inorganic phase that is characteristic of good hardness, chemical resistance,