Epoxy-Matrix MMT-Filled Nanocomposite Coatings onto Aluminum Substrates

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ABSTRACT

Epoxy base nanocomposite coatings were prepared by using organomodified montmorillonite (MMT) as filler and aluminum as substrate. A fast fabrication procedure was utilized so as to investigate the feasibility of industrial processes. After optimization of the coating process conditions, MMT filled coatings were produced by changing the MMT content and the mixing time. Many tests were performed to evaluate the coating performances: scratch and wear test, surface and gloss analysis. The effect of the MMT content on the coating properties is noticeable but not always ameliorative. On the other hand, it is questionable if the direct strengthening effect of the MMT particles is stronger than the indirect effect of the filler on the coating thickness. Anyway, best performances were measured in the case of low MMT content even if data scattering can be high.

Keywords: Coating, Epoxy Matrix, Montmorillonite, Nanocomposite, Surface Analysis

INTRODUCTION

Metal and ceramic surfaces often need to be protected and organic coatings provide a good technical solution because of their ease of application at reasonable cost. Coating performances are influenced by the adhesion with the substrate as well as by intrinsic properties of the organic film. Several fillers and matrices are commercially available and can be selected in dependence of the specific application and their mutual affinity. In particular, layered materials, such as smectite clays (e.g., montmorillonite, MMT), have attracted intense

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research interest for the preparation of polymer nano-composites because of the properties of their lamellar elements such as high in-plane stiffness and strength, and high aspect ratio (Pinnavaia, 1983).

MMT filled resins can also be used for metal coating but high processing times, difficulties in nano-filler exfoliation and the need to define and optimize a proper coating technology are still problems to solve. In this regard, Kowalczyk and Spychaj (2008), introduced organophilic MMT (2.5 and 5 wt%) in waterborne and solvent-type epoxy coating materials: hardness, scratch resistance and abrasion strength were positively modified by the nano-filler. A year later (Kowalczyk & Spychaj, 2009), they also studied the dispersion of MMT in epoxy paints, and discussed the important role of dosage, modification type and incorporation method. Pascual-Sánchez et al., 2010, deepened the effect of adding different amounts (0.5-3 wt%) of organomodified MMT to diglycidyl ether bisphenol A (DGEBA), cured with isophorone diamine at different temperature, on the viscoelastic, topographical and gelation properties of epoxy resin. The particle size distribution depended on the amount of nanofiller and an increase in the curing temperature was required to obtain the intercalation of the epoxy into the MMT. Epoxy/MMT composites showed higher storage modulus in the rubbery region and this improvement imparted by MMT organoclay was related to tactoid intercalation within the epoxy matrix. Therefore, the key factor is the nano-clay intercalation.

The optimal filler content is an important aspect to deal with and it is strictly dependent on the adopted mixing technology. Zaarei et al. (2010), measured the effect of the nano-clay content on physical and mechanical properties of epoxy coatings, such as abrasion and impact resistance, hardness, and flexibility. They took care of the dispersion process which was performed by means of high-shear mixing and ultrasonication. The introduction of organoclay up to 4 wt% in coating systems resulted in improvement in hardness (micro and Konig) and abrasion resistance whereas an increase in the impact resistance and flexibility was measured only up to 3 wt%. They explained this anomaly with the agglomeration of the clay particles for high clay-loading compositions. In their study on the influence of the nanocomposite on the properties of an epoxy-based powder coating, Piazza et al. (2011a) observed that the interaction of the MMT with the polymeric matrix, associated to the aspect ratio, resulted also in better functional properties such thermal stability, and adhesion to the metal substrate. In another study, Piazza et al. (2011b) also discussed that the nanoclay increases the glass transition and crosslinking temperatures and also enhances the thermal stability of the coating. Recently, Armstrong et al. (2012) have evaluated the antimicrobial properties of epoxy-polyester powder coatings containing silver-modified nanoclays. They observed that silver-modified nanoclay (AgMMT) fully inhibited the growth of bacteria, but powder coatings of AgMMT dispersed in epoxy/polyester resin exhibited no antimicrobial effect.

Scientific literature shows that the main problem to face is the nano-filler exfoliation to obtain high material performances with low filler content. High mixing times could lead to high levels of exfoliation but problems could occur in the case of liquid processing because of the increase of the resin mixture viscosity. On the other side, in order to develop new industrial applications, it is important to reduce processing time. This problem has been already faced by the authors in a previous work (Lucignano & Quadrini, 2008) by using a different resin matrix: polyester-MMT nano-composite coatings were prepared by the in situ intercalative polymerization method. Coatings with nano-clay content ranging from 1 to 5 wt%, were deposited on aluminum and high density polyethylene substrates by spin coating. A fast fabrication procedure was utilized as 1 hr was sufficient to prepare each coated sample. Mechanical tests were performed on the nano-composite coatings by macro-indentation and an increase in the coating strength was measured up to 3 wt% nano-clay content for both substrates. By means of the same experimental procedure, thick films
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