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Alkyd-clay nanocomposite coatings enhance anticorrosion and mechanical properties

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Exfoliated organo-modified montmorillonite clays in alkyd resins improve the barrier and mechanical properties of polymeric coatings for metal substrates.

Corrosion is an electrochemical phenomenon in which metal degrades by reacting with moisture in an oxygen-rich environment.[1] This undesirable process reduces the overall performance of the material. Organic polymeric resins such as epoxies,[2] polyurethanes,[3] and polyesters[4] have traditionally been used to reduce corrosion. Such coatings act as a physical barrier against the diffusion of corrosive species that are present in the atmosphere. However, polymeric coatings are not permanently impenetrable. The presence of small defects leads to ions (i.e., that are present in the atmosphere) diffusing through the coating and attacking the metal substrate. A second line of defense can be implemented against this process by incorporating various inorganic nanoscale materials that increase the anti-corrosion performance of the coating matrix.[5]

Polymer/clay nanocomposites (NCs) have attracted considerable attention for such application because of the superior properties that they achieve compared with their pure polymeric counterparts (in terms of, for example, the Young's modulus,[6] strength,[7] toughness,[8] and barrier performance[9, 10]). The mechanical properties of NCs are far superior to those of microcomposites based on similar materials. This is because nanoclays form 2D particles with very high aspect ratios when they are exfoliated in a polymer matrix. Furthermore, the platelike structure of nanoclays creates an elongated path by which ions are able to reach the metal substrate, thus increasing the anti-corrosion performance of the coating (i.e., its barrier property): see Figure 1. Previous efforts have focused on the integration of nanoclays into epoxy and polyurethane for the development of clear coating systems. However, research into the effects of nanoclays on protective paint systems (e.g., those based on alkyd resins), which typically have low mechanical and barrier properties, have not previously been studied.

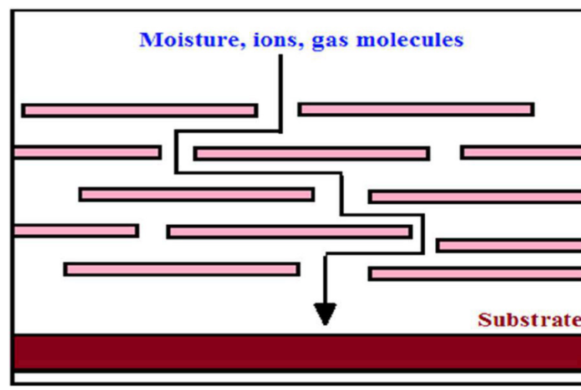

Figure 1. Schematic showing a polymeric/nanoclay coating on a metal substrate. A torturous path for moisture, ions, and gas molecules is created by integrating exfoliated nanoclay platelets (pink) in an alkyd resin, thus reducing corrosion of the substrate.

To test the effect of nanoclay on the performance of alkyd-based paint systems, we integrated exfoliated nanoclays into an alkyd polymeric system and subsequently investigated the performance of the resulting NCs. We thoroughly characterized the modified clay by Fourier transform infrared spectroscopy (FT-IR), thermogravimetric analysis (TGA), and x-ray diffraction (XRD).

To fabricate the NCs, we organically intercalated montmorillonite (O-MMT) into the alkyd using oleylamine. We synthesized alkyd-clay NCs with 1, 3, and 5% intercalated-clay loadings via the aid of external forces (such as high shear and ultrasonication). After fabrication, we used XRD to investigate the extent of the dispersion and exfoliation of the nanoclays (at a range of filler loadings) within the alkyd matrix. Our results revealed that nanoclay layers were exfoliated in the NCs at loadings of up to 3% O-MMT. At higher loadings, we observed a mainly intercalated structure due to the agglomeration of clay platelets (which we attribute to crowding of the platelets).

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Our investigations into the mechanical and thermal properties of the fabricated NCs showed that the incorporation of exfoliated nanoclays into the polymer/alkyd system resulted in enhancements to performance. By using TGA, we found that the decomposition temperature increased at higher nanoclay loadings. Furthermore, dynamic mechanical analysis showed an increase of the storage modulus (by 88% in the rubbery state and 8% in the glassy state) with a 3% nanoclay loading. We attribute these results to the uniform dispersion of a large number of clay platelets in the NCs. At higher loadings, however, the composites exhibited inferior mechanical properties (due to agglomeration).

To demonstrate the barrier effect of NCs toward corrosive species, we fabricated an enamel coating—comprising alkyd resin/nanoclays with additional pigments and additives—and performed a salt-spray analysis. We found that the presence of nanoclays at loadings of up to 3% led to an improvement in the corrosion resistance of the coating. Specifically, clay loadings of 3% doubled the time span before corrosion was observed. These results suggest that maximum exfoliation occurs at loadings of up to 3%, resulting in the creation of a very effective torturous path. The length of this path means that ions have much farther to travel and, as a result, far less corrosion occurs in the enamel-coated metal.

In summary, we have found that the addition of exfoliated nanoclays to an alkyd resin greatly enhances the mechanical, thermal, and barrier properties of the resulting NC. Based on our characterization, we found that the most significant enhancement occurs at clay loadings of 3%. At higher loadings, we observed a mainly intercalated structure, which arises due to the agglomeration of clay platelets. Our results suggest that the properties of alkyd-based paint systems are significantly enhanced by the addition of exfoliated nanoclays, particularly in terms of the corrosion resistance of the resulting NCs. In our future work, we will explore this concept for water-based paint formulations.

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