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Novel Waterborne Nanostructured Coatings

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Abstract : Paints and coatings industries are among the first to take advantage of nanotechnology by incorporation of nanoparticle in coatings or in-situ creation of nanostructured coatings. In the present study, waterborne silane based coatings for lightweight alloys (aluminum and magnesium alloy) have been developed. Lightweight alloys have the competitive advantage of modern aerospace and automotive structures because they enable achievement of high structural efficiency, improved fuel efficiency without scarifying mechanical strength. However, these alloys undergo sever corrosion when exposed to continued aggressive environment. Coatings restrict the access aggressive environmental stresses to the metal as well as interfere with metal dissolution reaction. This is the key to corrosion control by protective coating. Results show that the coatings are uniform, transparent and crack free. It is found that the corrosion current of coated substrate reduced by one to three orders of magnitude than bare substrates. UV-visible spectroscopy and UV-weathering suggest that these coatings are suitable for outdoor application. Excellent UV-resistance is observed for HMMM cure coatings and alkyd incorporated coatings. It was observed coating have no glass transition coating in the temperature range of 30-700°C. Alkyd incorporated sol-gel coating shows excellent thermal stability upto 300°C. All the coatings have shown chemical interaction with substrate which leads to their excellent adhesion. Thus, the use of nanostructure sol-gel coating and their further modification with organic polymer have to be regarded as a consistence further development of the new innovative sol-gel technology which is characterized by the combination of novel and conventional method of the formulation of coatings. These coatings are environmentally-friendly coatings of a new era of high technology for protection of material from environmental stresses and to get preferred properties.

Key words : silanes, waterborne, nanostructured coatings, UV stability

Paints and coatings industries are among the first to take advantage of nanotechnology by incorporation of nanoparticle in coatings or in-situ creation of nanostructured coatings. Nanostructured coatings have nano-level of interaction among the various coating components which leads to the smooth, strong and more durable coating. These coatings are used generally used where excellent end user properties such as improved corrosion resistance, UV stability and high hardness with better flexibility are required. Sol-gel process is generally used to produce these nanostructured coatings with practically all type of chemical composition at low temperature on metals, glass and plastic of various shapes through the use of liquid solution (aqueous and non-aqueous). The most common precursors for these coatings are silanes which are hybrid molecules containing functional organic groups, such as methoxy or ethoxy groups and chlorine, amine, sulphur or epoxy on inorganic silicon atoms. These ethoxy or

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methoxy groups on hydrolysis forms silanol groups Si-OH which can react with metal hydroxide groups on the substrate surface, thus forming a Si-O-M covalent bonded metal/film interface. This is the beauty of these nanostructured silane coatings which donot requires metal oxidation or species reduction processes, unlike chemical conversion treatments such as chromating, zirconium or titanium conversion, in the film deposition mechanism. Furthermore, silanes are environmentally friendly.

In the present study, waterborne silane based coatings for lightweight alloys (aluminum and magnesium alloy) have been developed. Lightweight alloys have the competitive advantage of modern aerospace and automotive structures because they enable achievement of high structural efficiency, improved fuel efficiency without scarifying mechanical strength. However, these alloys undergo sever corrosion when exposed to continued aggressive environment. Coatings restrict the access aggressive environmental stresses to the metal as well as interfere with metal dissolution reaction. This is the key to corrosion control by protective coating.

The first step of coating formulation was the preparation of primary sol which involves the hydrolysis and condensation of methyltrimethoxysilane (MTMS) and 3-glycidoxypropyltriethoxysilane (GPTMS) in aqueous medium. It was followed by the further modification of primary sol with conventional organic polymer such as waterborne alkyd and waterborne polyester to improve the technical as well as economical limitation of sol-gel coatings. Two amino functional organosilanes namely 3-aminopropyltriethoxysilane (1N), N-(2-aminoethyl)-3-aminopropyltrimethoxysilane (2N) and hexamethoxymethylmelamine (HMMM) were used as hardeners. Coating materials were characterized using SEM, AFM, TEM, TGA/DSC. Corrosion resistance and hydrophobicity of coated substrate were evaluated by EIS, potentiodynamic polarization and contact angle measurements. Furthermore, UV stability of coatings was studied using UV-visible spectroscopy and UV-weatherometer to see performance of coating in outdoor application. Hardness, abhesion and flexibility of coating on substrate were also determined.

Results show that the coatings are uniform, transparent and crack free. It is found that the coatings act as barriers that restrict the diffusion of corrosive agents such as water, oxygen and chloride ions towards the coating/metal interface. The reduction in corrosion current of coated substrates by one to three orders of magnitude than bare substrates was observed. UV-visible spectroscopy and UV-weathering suggest that these coatings are suitable for outdoor application. Improvement in thermal and UV stability of conventional coatings were observed with addition of silane in coatings. All the coatings have shown chemical interaction with substrate which leads to their excellent adhesion.

Thus, the use of nanostructure sol-gel coating and their further modification with organic polymer have to be regarded as a consistence further development of the new innovative sol-gel technology which is characterized by the combination of novel and conventional method of the formulation of coatings. These coatings are environmentally-friendly coatings of a new era of high technology for protection of material from environmental stresses and to get preferred properties.