DEVELOPMENT OF NOVEL POLYMERIC CORROSION INHIBITORS FOR ALUMINUM AND STEEL APPLICATIONS

Users are increasingly demanding innovative materials and particularly coatings to fulfill a variety of functions. Fundamentally, coatings and paints have to effectively protect the surfaces and interfaces of all materials, including those still in development. Modern surface technology, which combines empirical know-how and knowledge of materials with computer based algorithms based on physical-chemical principles, provides a forward-looking or, if necessary, fast-reacting platform for studying this. The bilateral project involving Straetmans High TAC GmbH and the Adhesion and Interface Research as well as Paint/Lacquer Technology departments of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Bremen, demonstrates how the concept of molecule adsorption, namely the concentration of molecules at interfaces, can provide the basis for the development of both temporary protective systems and additives for long-life coatings.

Background

With regard to the future selection of adsorbing molecules, scientists not only have to consider the chemical and material-related requirements and economical aspects but also have to comply with statutory boundary conditions as laid down, for example, by the REACH Regulation. For the sustainable development of new coatings, two main design options will probably be of interest: intelligent formulations which do not demand the synthesis of new substances, and the path followed in this project via polymers which are usually not very hazardous.

Tasks – Project description – Procedure

In nature, surface-active molecules play an important protective role in cell membranes. Such amphiphiles are chemically non-reactive and use the concept of self-organization to form closed layers. In order to develop novel amphiphilic polymers, it saves time and is helpful to use computer-aided modeling to study the organization of molecules of differing structure in liquid media and on substrate surfaces. In the presence of a liquid application medium, such polymers form submicroscopic micelles and at interfaces with solid substrates there is a uniform layer of adsorbed molecules whose thickness is uniform and may be tailored based on the molecular weight. Figure 1 shows, for instance, intermediate steps for different

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polymer molecules when establishing the association behavior in a polar solvent and the adsorption behavior on a hydrophilic substrate surface. The structures that form from the polymer molecules are shown in green.

The objective of the project was to transfer this amphiphile-based concept to chemical synthesis with reactive and structural base elements that can form head, tail, or spacing units in the resulting polymer molecules. Based on the simulation results, their relative arrangement in the molecules can be attuned to be suitable for distinct liquid media. The chemical reactivity of the resulting molecules can be customized by partial or full incorporation of virtually non-reactive molecular end-groups. This means that neither the desired coating formulations nor the substrate surfaces are altered by chemical reactions with inhibitor molecules in a hardly predictable way.

The developed polymer molecules form thin and closed layers on immersion of the metal substrates in inhibitor solutions or dispersions. Particularly effective molecule layers have a corrosion-inhibiting effect and can – when applied in this way – provide temporary corrosion protection. Surface analysis of sheets of AA 2024 aluminum alloy by x-ray photoelectron spectroscopy, energy-dispersive x-ray analysis, and scanning electron microscopy show that about a 0.01 micrometer thick protective layer forms and that, following a salt-spray test, there is only a slight increase in the thickness of the aluminum oxide layer on the substrate. As Figure 2 illustrates, coated sheets exposed to the salt-spray test for 250 hours show no signs of corrosion (bottom image), unlike sheets not protected with inhibitor polymers (salt-spray test for 24 hours, top image).

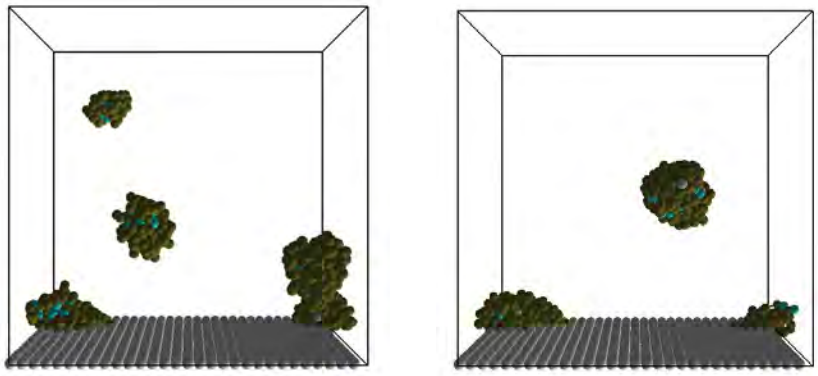

Fig. 1: Simulation of the early phases of association and adsorption of polymer molecules.

2 *Corrosion protection effect of a polymer inhibitor layer on aluminum developed in collaboration with Fraunhofer IFAM (top: uncoated, bottom: coated).*

The fact that a corrosion-inhibiting effect was achieved on sheets of steel with one and the same polymer formulation confirms that the physical concept of layer formation modeled in the simulation work is effective.

If the inhibiting effect of the amphiphilic polymers is also retained in cured coating systems, it can be synchronized with the action of other corrosion protection systems in the coating. The test studied novel coating systems with polymeric corrosion inhibitor additives on AA 2024 sheets compared to coatings without corrosion inhibitor additives. The layer disbonding in the salt-spray test and thread growth in the filiform corrosion test were measured. The test results are summarized in Table 1. It can be seen that several chemically different formulations of the novel coating systems have advantageous properties.

Results and perspective

The medium-sized project partner benefited from the interdisciplinary procedure. The development time for marketable products is reduced compared to a purely empirical material development strategy. Polymeric agents, which based on physical principles introduce additional functionalities into coatings and crosslinking polymers, contribute to sustainability and the efficient use of resources.

	Infiltration in the salt-spray test after 1008 hours		Thread length in the filiform test after 504 hours	
Coating system	**Without inhibitor**	**With 2 % inhibitor**	**Without inhibitor**	**With 2 % inhibitor**
Water-based 2-C epoxide coating	6 mm	2 mm	9 mm	3 mm
Solvent-based 2-C epoxide coating	7 mm	2 mm	12 mm	3 mm
Alkyd resin coating	12 mm	4 mm	26 mm	7 mm
Alkyd-melamine coating	After 240 h: Break	After 480 h: 2 mm	After 168 h: Break	After 240 h: 5 mm

Tab. 1: Test results on aged coating systems.

Project funding

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