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Electrodeposition of Paint

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1. Introduction

Electrodeposition of paint (EDP) is a process, in which an electronically conducting substrate is dipped into an aqueous solution of water-borne paint. In most of the cases, the binder is an organic polymer which contains carboxylic groups, thus forming a polyelectrolyte, which provides, at least in the partially neutralized state, some ionic conductivity to the solution. If the substrate is polarized anodically versus a counterelectrode, for which the walls of the tank are usually used (cf. Figure 1), current flow through the system causes electrochemical reactions at the phase boundary substrate–bath, leading to electrocoagulation of the paint.

According to this definition, EDP is an electrochemical surface technique which combines polymer science and electrochemistry. More precisely, it can be classified as a part of organoelectrochemistry, where organic molecules interact with an electrochemical electrode. This process is now applied worldwide to provide the first layer of paint onto car bodies and other industrially manufactured metal mass ware. Today more than 1000 big electrocoat installations are operating for primers and one-coat paint systems. Every year, an area of more than 1000 square miles of paint is now deposited by this process. With an average thickness of about 1 mil, this means an annual turnover of about $10^5$ tons of organic material at electrochemical electrodes. This is the

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same order of magnitude as the largest electro-organic process, the electrosynthesis of adiponitrile.

Another "electric" painting process which has been used for a long time is the electrostatic spray coating. The electric field strength $F$ is determined by the dielectric constant $\varepsilon$ in the medium and the surface density of electric charge $Q_A$ in the Gauss equation

$$F_{\text{stat}} = \frac{1}{\varepsilon \varepsilon_0} Q_A$$

(1)

Thus the field strength in the electrostatically coated film is appreciably lower than in the air gap between both electrodes. On the other hand, in the EDP process, the field strength of the electric "flow fields" is given by the specific electrical conductivity $\kappa$ and the current density $j$ in the layers according to

$$F_{\text{dyn}} = \frac{1}{\kappa} j$$

(2)

The specific conductivity in the film is lower by 4–5 orders of magnitude in comparison to that of the bath. This causes a very high electric field strength in the film, as is schematically represented in Figure 2.

Processes that can be directly compared with the EDP process are dip painting and electrostatic or nonelectrical spray coating. The technical success of the EDP process is due to certain outstanding advantages, which are summarized in Table 1.(6)

The equipment for the new process is expensive and leads to a continuous operation rather than a batchwise application. Together with the relatively