Organic coatings are widely used in protection of metallic substrate against corrosion.\textsuperscript{1} It is generally accepted that the coating efficiency for outdoor applications depends on its weathering resistance, barrier and adhesion properties of the coating and the degree of aggressiveness of the environment and so on. Many factors may accelerate coating degradation namely ultraviolet (UV) radiation, water and moisture, elevated temperatures, chemicals, thermal variations, presence of molecular and singlet oxygen, ozone and abrasion or other mechanical stresses. Among the above mentioned factors, degradation of organic coatings is mostly promoted by simultaneous effect of: UV radiation, moisture, heat and chemicals. In a barrier protective coating, as the polymeric backbone of the coating film is slowly broken down by UV light, the coating’s barrier properties is worsened. The ultraviolet range of the sunlight spectrum is an important damaging factor for the exterior coatings.\textsuperscript{2,5} To decrease the probability of occurrence of such failures, coatings that are exposed to UV light during their service life are mostly formulated based on UV-resistant polymeric binders, such as acrylics and aliphatic polyurethanes.\textsuperscript{6}

Generally, coatings used in more challenging applications, such as automotive, aerospace and exterior wood coatings, contain additives, to absorb UV light and protect the coating and the substrate from photo-induced degradation reactions. Typically, these additives are incorporated in coating formulations at concentrations of less than 5 percent. Some of the more common chemical classes of organic UV absorbers are benzophenones, benzo triazoles, triazines, malonates, and oxalanilides.\textsuperscript{7} These additives, due to their relatively low molecular weight, may migrate from the applied coating, either to the coating surface or into the substrate. On the other hand, since these compounds are organic materials, they are themselves susceptible to a number of degradation mechanisms.\textsuperscript{5–10}

Many metal oxides are known to absorb UV radiation. The most common of these oxides are zinc oxide (ZnO), titanium dioxide (TiO\textsubscript{2}), cerium oxide (CeO\textsubscript{2}) and iron oxide (Fe\textsubscript{2}O\textsubscript{3}). Since these materials exhibit high indexes of refraction, they render the coatings semi-transparent. Even high refractive index particles with diameters less than 100 nm can be incorporated into a coating matrix to give visibly transparent or semi-transparent films. Nano-sized ZnO is a candidate for UV protection of coating materials. Since they are inorganic and particulate, they have extra advantages of being stable and non-migratory within an applied coating, thus allowing them to potentially offer better effectiveness and a longer service life.\textsuperscript{11, 12}

The degradation of organic coatings is often estimated by visual inspection and different physical, chemical, mechanical and electrochemical methods.\textsuperscript{13} Electrochemical methods specially electrochemical impedance spectroscopy (EIS) could be used for evaluation of performance as far as data interpretation, water effect and degradation mechanism.\textsuperscript{14} Coupling electrochemical techniques with accelerated tests can result in new information concerning the protective properties of coatings exposed to accelerated weathering conditions.\textsuperscript{15, 16}

In particular, electrochemical impedance spectroscopy (EIS) has been proven to be a very useful technique for the investigation of the performance of anti-corrosive coatings.\textsuperscript{17–20}

The aim of this work is to clarify the effect of exposure of an epoxy-based automotive electro-coating primer to UV light on its protective properties and to clarify the influence of a ZnO-based UV absorber on deterioration of the protective properties of the coating film using electrochemical impedance spectroscopy.

**Experimental**

**Materials and methods.**— Nano zinc oxide dispersion with a solid content of 40 percent, a density of 1.4 g/cm\textsuperscript{3}, a pH value of 8.1–8.6 and a mean particle size of less than 50 nm (Oxylink 3102) was kindly provided by Bucher AG. Waterborne resin dispersion and a pigment paste (CATHOGUARD 500) were obtained from BASF AG and mixed in a ratio of 6:1. The resin dispersion and the pigment paste have solid content of 40 ± 2\textsuperscript{a} and 66 ± 2\textsuperscript{b}, respectively. The mixture was diluted using DI water (electrical conductivity < 10 \(\mu\)S/cm) to a solid content of 20 percent. Nano ZnO was added to resin component before mixing with pigment paste and further dilution. The details of the preparation of the electro-coating bath have been mentioned elsewhere.\textsuperscript{20} The paint films, were deposited on phosphated steel panels at 190 Volts for 3 minutes at an active anode to cathode ratio of 1:6. The films were then rinsed by DI water and after analyzing DSC curve, curing behavior of coatings and also MEK rub out test they were baked for 20 minutes at 165\textdegree\textsuperscript{c} in an electrical laboratory oven and then the dry film thickness is 20 ± 1 micron.

**Equipments.**— The accelerated weathering tests were carried out by exposing the coated panels in a QUV chamber (QUV weathering Tester-model QUV/spray, Q-Lab Co.) for duration of 1080 hours (45 days). In the QUV chamber, the panels were cycledly exposed to UV-B radiation (315nm) at 50\textdegree\textsuperscript{c} for 8 h followed by water condensation at 40\textdegree\textsuperscript{c} for 4 h according to ASTM G53 standard.

An IVIUM Technologies electrochemical impedance spectrometer was used to study the electrochemical and corrosion behavior of