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Editorial

Powder and High-Solid Coatings

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Abstract: This Special Issue presents a series of research papers and reviews about the actual trend of powder and high solid coatings which show the advantage of great environmental sustainability by avoiding the massive use of organic solvents. Moreover, some very interesting studies exist on the move from a simple protective layer to a smart coating with additional properties, both for the aesthetic and functional aspects.

Keywords: corrosion protection; graphene; aluminum trihydrate; pearlescent pigments; marine atmosphere; rust converter; colloidal silver; scanning electrochemical microscopy; electrochemical tests; laboratory accelerated test

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Organic coatings, often referred to as paint or varnish, are the most popular method of protecting metal substrates from corrosion. Thanks to their excellent protective properties, organic coatings have been applied increasingly more often over the years.

Let us introduce some basic information on organic coatings.

This type of coating consists of four elements. First, a binder, which constitutes the polymer film and is responsible for adhesion with the metal substrate and the cohesion of pigments and additives. We then have pigments or insoluble solid particles with different purposes, such as corrosion inhibition, providing color, modifying the surface roughness and creating surface effects. The third element, additives, are chemical compounds or particles of organic or inorganic type which are added to modify the properties of paints, such as anti-foamers, stabilizers and rheology modifiers, and, fillers to reduce the cost of the organic coating. Finally, the solvent, present in many painted systems but not in all and used to keep the paint in a liquid state during storage and application. The binder and pigments are solubilized or dispersed in the solvent.

We will later see the gradual evolution of the painted systems which are the theme and purpose of this Special Issue.

Paints can be classified according to the type of binder. Each type of binder has characteristics that make it more or less suitable for certain uses and environments; for example, applying it as a top coat or a primer.

The epoxy matrix is excellent as a primer due to its corrosion resistance and adhesion properties. Otherwise, it is less suitable for use as a top coat due to its poor UV resistance. On the other hand, acrylic binders have excellent resistance to aging and abrasion. At the same time, they possess a surface appearance that makes them ideal candidates as finishing layers. Polyester resins are also interesting for this last use as they have good mechanical properties together with a low cost. Conversely, the cost penalizes the polyurethane-type binders which, due to their valuable properties of resistance to aging and abrasion, combined with adhesion and aesthetic properties would be very attractive.

There are different types of paints. The oldest and still most widely used are based on organic solvents and therefore present environmental issues. The organic coating (binder, pigments and additives) that dissolves in the solvent is what forms the protective layer following the evaporation of the solvent, hence the title of this Special Issue.

In fact, to reduce the environmental impact, risk of fire and potential threat to the operator's safety, alternatives to organic solvents have been sought more and more frequently. Water-based paints initially showed a reduced use, mainly due to their limited protection performance compared to traditional solvent-based paints, but they have experienced a tremendous level of development in recent years.

With the aim of reducing the use of solvents as much as possible or eliminating them altogether, the use of high solid paints is widespread in North America. On the other hand, in Europe, powder paints are preferred to solve environmental problems. In this case, a coating is applied to the substrate starting from solid particles in the form of a powder, which contain both the binder, the pigments and the additives. By applying an electric field, suitably bonded particles are attracted to the substrate. By adhering to the substrate, being insulators, they favor the deposition of subsequent particles in the areas of substrate that remain uncovered. By means of a curing heat treatment, the chains cross-link and the protective coating is obtained.

Regarding the use of powder paints, scientists have often wondered if some components, additives or pigments that are used in liquid paints can also be used in this type of coating. The transfer is not immediate since a substance that is soluble in an organic solvent is unlikely to be easily dispersed in a solid matrix. Moreover, there is a risk of not obtaining uniform dispersion but rather the formation of accumulations and clusters. It is therefore necessary to carry out a bonding treatment so that the different components comprising the paint (matrix, pigments and additives) are simultaneously present in a single grain of powder. Even in the instance of managing to homogeneously disperse the components, there is still the question of whether the additives and pigments show the same behavior in powder paint as they do traditional solvent-based paint [1,2]. Hence, the article by Weihong Li et al. "Investigation of the Performance of ATH Powders in Organic Powder Coatings" [3], which evaluates the optimization and behavior of aluminum trihydrate (ATH), one of the most widely used fillers in solvent-borne coatings and polymer industries, introduced in a powder system.

One of the positive aspects of paints is their possibility of being deposited on different types of metal substrates, such as steel, cast iron, aluminum and copper alloys. Paints find endless potential applications on products with different functions requiring use in the most varied environments, not just in non-aggressive indoor environments or in natural environments. In this case, to ensure the expected service life it is necessary to carefully evaluate the aggressiveness of the environment and the required protection time to consider the possibility of mechanical damage to the coating and the possibility of carrying out maintenance operations.

One of the most critical applications for a protective system is the protection of marine and offshore structures. The marine atmosphere is a challenge for the designer, due to the high humidity, the presence of aggressive ions such as chlorides, the high insolation and the difficulty of restoration [4,5]. Usually, for these applications, spray-deposited solvent-based paint systems consisting of several layers and a very high thickness are used. Turning to powder and high solid coatings for environmental reasons, the question arises as to whether these types of coatings can guarantee performances that are similar to those of traditional solvent-based paints. Thus, the review by Krystel Pélissier and Dominique Thierry entitled, "Powder and High-Solid Coatings as Anticorrosive Solutions for Marine and Offshore Applications? A Review" [6] is very interesting, as it illustrates all the important aspects that are necessary to obtain corrosion protection with these types of paints in high-performance applications. Exposure tests in very aggressive natural environments (Florida test or Arizona test) or accelerated laboratory tests, such as continuous or cycled salt spray, are traditionally used to evaluate the performance of a painted system; however, these tests present some critical issues. They often take a very long time, from months up to several years, to establish whether the painted system shows the desired protective performance. Electrochemical techniques, and in particular Electrochemical Impedance Spectroscopy (EIS) [7], help scientists by allowing a reduction in evaluation times and providing many data that enable a better understanding of the protection mechanism of a coating, as well as the evaluation of the reduction in protective properties over time. In addition to traditional electrochemical techniques that require a fairly large test area, in recent years, localized electrochemical techniques have been developed and used that enable greater depth of study of the corrosion and protection mechanisms by analyzing very small samples at a microscopic level. Here fits the work of Ricardo M. Souto and co-authors, entitled, "Uses of Scanning Electrochemical Microscopy (SECM) for the Characterization with Spatial and Chemical resolution of Thin Surface Layers and Coating Systems Applied on Metals: A Review" [8]. As mentioned, scientific research in the field of paints is aimed at reducing the environmental impact by seeking alternative solutions that are less polluting and more efficient. For this reason, innovative pigments, new additives and green corrosion inhibitors are constantly being studied. In recent years, graphene G and graphene oxide GO, consisting of thin sheets of sp2 hybridized carbon, have also aroused great interest in the field of paints [9–11]. However, the dispersion of graphene-based flakes is not simple and is susceptible to clustering.

An example of the introduction of graphene oxide in a painted system is present in the work by Carmen Perez and coauthors, entitled, "Influence of Graphene Oxide Additions on the Corrosion Resistance of a Rust Converter Primer" [12]. To study the effects of flakes on the protective properties of primers, the GO was included in five rust converters, identifying the optimal percentage between the converter and the GO sheets.

In recent years, organic coatings have also found further applications that are different from the traditional corrosion protection function of metal substrates. Recently, coatings that offer other characteristics or that respond to an external stimulus with a different or unexpected response have been developed and studied. These materials represent the so-called smart coatings. The introduction of graphene was also aimed at obtaining an organic coating with a high surface conductivity. Other examples may be the introduction of NIR near infrared reflective pigments to produce coatings for roof applications that allow the temperature of buildings to be passively controlled, with the aim of reducing the effects of urban heat islands.

Applying organic coatings to surfaces that possess antimicrobial features in order to reduce the necessity of a regular disinfection has also gained great interest following the COVID-19 pandemic. One of the most effective methods is through the introduction of silver particles into the paints, thanks to the recognized antimicrobial action of this element [13,14]. Some questions remain; for example, how much paint is needed to make the coating effective without an excessive increase in the cost of production or a reduction in the other properties of the paint? There is also the need to disperse the silver as uniformly as possible and ensure its presence in the outermost layers of the deposit so that the antimicrobial action can be implemented. This topic is discussed in the article entitled, "Durability of Acrylic Cataphoretic Coatings Additivated with Colloidal Silver" [15].

Finally, let us revisit one of the main reasons that lead paints to be the most used type of coating: color. Normally, in scientific research, no attention is paid to color. No reviewer asks the authors about the color of the paints they are studying if this has not been indicated. Very little research is aimed at evaluating the color of organic coatings. Studies are usually limited to the engineering properties of the coatings (corrosion resistance, abrasion resistance, hardness, electrical and thermal insulation, thermal characteristics); however, color is a key aspect. The first thing we notice about a product is its shape and surface, its texture and color. We desire a specific color for our car and a great many other objects., The world would be a sad, black and white (or rather gray, green and brown) place if we only thought about the corrosion protection properties of a paint. We all have the red Ferrari, the gray Porsche, Hermès orange, and other iconic colors in mind.

In recent years, always with the aim of customizing and diversifying the product, new pigments have been introduced that produce optical effects. Metallic, micaceous and pearlescent are the possibilities offered by some organic pigments [16,17]. The pearlescent effect is obtained with pigments that have a superficial oxide layer with different thicknesses from area to area so that an interference with light enables the observer to perceive different colors. Once only used in niche sectors, now more and more of these pigments are employed in common products, hence the need to evaluate not only the corrosion protection properties but also the perceptive aesthetic features of the paints. Today, it is important to be able to maintain the surface appearance of organic coatings over time even in very aggressive environments that are subjected to solar radiation. This topic is covered in the latest paper of the Special Issue entitled, "Study of the Durability and Aesthetical Properties of Powder Coatings Admixed with Pearlescent Pigments" [18].

To conclude, we can say that paints that are made from simple organic layers with toxic pigments (such as red lead) and sad colors have evolved and continue to evolve, presenting properties that were once unexpected, both from a technical and aesthetic point of view.

We can confidently say that the times when "Any customer can have a car painted any color that he wants, as long as it is black" are definitely a memory.

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