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Introduction

Materials always have been of crucial importance for society. The wide range of the presently existent materials provides a large variety of properties that have been put to full use for many applications. However, applications often require a combination of properties or, actually, different properties at different locations and times, dependent on the circumstances at hand. Hence, combinations of materials are important and, since properties at surfaces are usually required to be different from those in bulk, coatings have become an important branch of materials science.

1.1 Scope

For nominally single-phase bulk materials, one can distinguish between inorganic, polymeric, and metallic materials. Furthermore, one has multiphase bulk materials, in which two or more clearly distinguishable phases coexist. If synthetic, they are usually called *composites*, but nature provides us with *bio-composites*, such as wood (with cellulose acting as skeleton, hemicellulose as matrix, and lignin as binder). A similar distinction can be made for coatings. In principle, each materials type can be applied as a coating over any of the other materials type, which is then used as substrate. However, while inorganic coatings are typically applied on metals and polymers, and metals coatings are mainly applied on metallic, inorganic, and polymer materials, polymer coatings are applied on almost any substrate, including composites. Actually, many (if not most) coatings can be considered themselves as multiphase materials, as frequently several different layers are applied, with one (or more) of the layers containing a particulate filler. In this book we restrict ourselves to *polymer coatings*, irrespective of the substrate. Note that surfaces of almost all metals are covered with an oxide, so that polymer coatings on metals or oxide substrates contain rather similar coating–substrate interfaces. A further distinction can be made with respect to coatings properties. One can consider the *mechanical* properties, like hardness and strength, the *aesthetic* properties, such as gloss and transparency, and a wide range of so-called *functional* properties, such as, a wettability or electrical conductivity. We will mainly focus on such functional coatings. Nevertheless, as the mechanical integrity and appearance of these

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coatings is of crucial importance, some of the mechanical characteristics and aesthetics are dealt with as well.

Furthermore, we will deal with the chemistry, physics, colloid science, and rheology relevant in coatings manufacture and processing, that is, we deal with *coatings science and technology*. This implies that we will cover complex interactions between all these aspects, and, hence, the order of presentation is to some extent arbitrary. Possibly superfluous, but it is useful to distinguish here between *paint* and *coating formulation*, a fluid or paste containing many (solid and liquid) ingredients that are applied on a substrate, for example, by brushing, rolling, or spraying, and *coating*, a cohesive, protective, and possibly decorative solid film that results from the application of the paint on a substrate. At different sections of this book, we will address either *paint-* or *coating-*related aspects, depending on the nature of the concepts discussed. The sequence of topics and the in-depth level of discussion that we choose for this book aim for clarity and easy intertwine of the different subjects and are based on several years of experience in teaching a course on this topic to master level students following a materials and polymers study track.

1.2 The Importance of Polymer Coatings

There are not many material applications in our modern society that are both so ubiquitously visible and usually unnoticed, as is the case with coatings. Some are used to give a good appearance to, for example, buildings, vehicles, and furniture without attracting the eye's conscious attention to their own existence; others are highly functional but invisibly embedded in devices, or just transparently covering other materials. Whether coatings are perceived as relatively *simple* such as, for example, protective layers or as a functional part of *high-tech* devices, they are in many aspects playing quite vital roles in the quality of our life.

The materials chemistry of *polymer coatings* is distinctively different from *polymers*. The term *polymer coating* suggests that such a coating comprises predominantly, if not solely, polymers, but there are also many examples in which inorganic materials actually dominate by weight. What these coatings do have in common is an organic polymer matrix or binder, the continuous polymer phase holding all constituents together. Bulk polymer materials can have quite high inorganic filler fractions too, but in this case their use is more related to structural properties (hardness/modulus, flexural strength, flame retardation) than to surface properties (color, hiding power, gloss, and reflectance). Moreover, structural polymer materials are still not as highly filled as coatings usually are, implying that in coatings the ratio of the values of the interface area to polymer matrix volume is much larger. Consequently, the performance of a polymer coating is strongly dominated by three main types of interfaces: coating–substrate (bottom), coating–air (top), and binder–filler (internal). It is important to remark that solid–solid, solid–gas, solid–liquid, and gas–liquid interfaces (e.g. in drying paints) also play a role.

More importantly, the chemistry and topology of the polymer phase are highly different in coatings as compared with bulk polymers. Whereas the vast majority of polymeric materials are thermoplastic in nature, most advanced polymer coatings are thermosets with the exception of waterborne coatings (where high molecular mass polymers are already easily accessible without crosslinking). Thermosets are infinite three-dimensional networks of covalently interconnected polymer segments. The reason for most coatings to be thermosets is that the network architecture offers the highest resistance of these thin polymer layers to solvents, chemicals, and mechanical stresses [1]. An intriguing feature of most polymer coatings is that they are applied as liquids (i.e. as paint or *formulatio*n), for ease of handling and spreading, but they need to be transformed from this obviously thermoplastic phase into the final thermoset state immediately after being applied on a substrate (in a crosslinking process typically called *curing*). This need for curing is inevitably reflected in the choices of material chemistry of such materials.

Another relevant aspect for polymer coatings chemistry is molecular mobility that obviously plays a central role in forming a uniform solid layer from a liquid phase as well as in achieving some functional properties such as self-healing behavior. Molecular mobility in a thermoplastic polymer can be easily envisaged by molecular motions of individual macromolecules that are mostly entangled but still largely independent. Material mobility in a thermoset material is highly hindered by the network structure, whether one considers the motions of the polymeric network segments themselves or the motions of unconnected small molecules diffusing through the network.

Finally, the functional requirements for a polymer coating are generally quite different from those for a structural polymer material. The two primary functions of a surface coating are decoration and protection. The decorative function relates to the appearance of the coated substrate, largely dominated by the appearance of the coating layer itself, and covers many aspects such as specular gloss and diffuse reflection, surface undulations, color perception, hiding power, transparency, cleanability, etc. The protective function relates to the underlying substrate, which has to be sealed off from external influences such as light, humidity, air, fungi, bacteria, dirt, chemicals, mechanical abrasions, and the like. Often this protective function is in close interplay with the underlying substrate, for example, in corrosion protection of metal-based substrates. It should then be clear that one often aims for a delicate mix of functional properties of a coating.

Nowadays also the functional behavior of coatings is of definite importance. During the last decade, extensive research has been carried out on functional coatings with easy-to-clean/self-cleaning, antibacterial or antifouling properties, mainly driven not only by industrial demand but also by academic interest. Such properties are strongly related to the surface characteristics, in particular to chemical composition and topography, as will be discussed in detail later. Finally, we note that one of the greatest advantages of using functional coatings is that with only a rather small amount of material, thin layer(s) of a few tens to hundreds of micrometers, it is possible to functionalize the whole substrate with little or no impact on other properties, such as mechanical strength, and, hence, functional coatings also add to the economics and sustainability of materials and devices.

As stated, coatings are ubiquitously present. To name just a few areas, coatings are important in:

- Transportation in which they usually provide a protective, decorative, and/or aesthetic function for the vehicles (cars, trains, aero planes, etc.) involved.
- Living environment in which they are used for protection and safety, for example, as hard coating with good anti-scratch properties and proper friction for kitchen cabinets, table tops, and other furniture.
- Healthcare where they can reduce contact with bacteria and viruses or provide a proper lubrication, for example, in catheters.
- Leisure where the most important example is (arguably) mobile phones and laptops, both with functional and decorative purposes.
- Industrial processes where coatings can be protective, for example, pipelines for transport of gas and fluids or membranes for proper separation/purification of specific components.
- Food and cosmetics where they act for protection, for example, as O_2 barrier.
- Energy where, for example, antireflective coatings are applied to solar panels to avoid the otherwise inevitable efficiency drop due to reflections.

The coatings market is larger than one might expect. The global demand for industrial coatings is estimated at $\approx 61.3 \times 10^9$ € in 2016 and projected to touch $\approx 87.6 \times 10^9$ € by 2022 [2], growing by a rate compounded annually at 6.1% between 2016 and 2022 with the Asia-Pacific region being the largest consumer (≈47%) and Europe the second one (≈21%). From Figure 1.1 [3, 4] it can be easily estimated that every person in the world spends about 17 € per year on coatings. With an increasing population and growing economy with a large demand on commodity high performance products, it is clear that coatings show a growing market with great challenges ahead that have to deal with reproducible and reliable large-scale production processes for the development of durable, easy-to-apply, cheap-to-produce/apply, and environmentally friendly and sustainable production methods.

Coatings are mainly used for protective and aesthetic (decoration) purposes, and several factors influence their life time. The first is what might be called the *weather factor*, that is, humidity (rain, ice), radiation (sunlight, i.e. UV radiation), and particles (sand, dust). The second is the *biological factor* containing the effect of algae, bacteria, and other living organisms. The third is the *human factor* including wear due to daily usage and unintended damage due to, for example, scratching. So, in short, coatings need to be resistant and durable. Since there is also a wide and increasing variety of applications, functional coatings have become more and more *tailor-made surfaces*. For instance, since damage of coatings can never be totally avoided, the introduction of a self-healing function is one way to repair the coatings properties and maintain a high performance throughout an extended service life time.

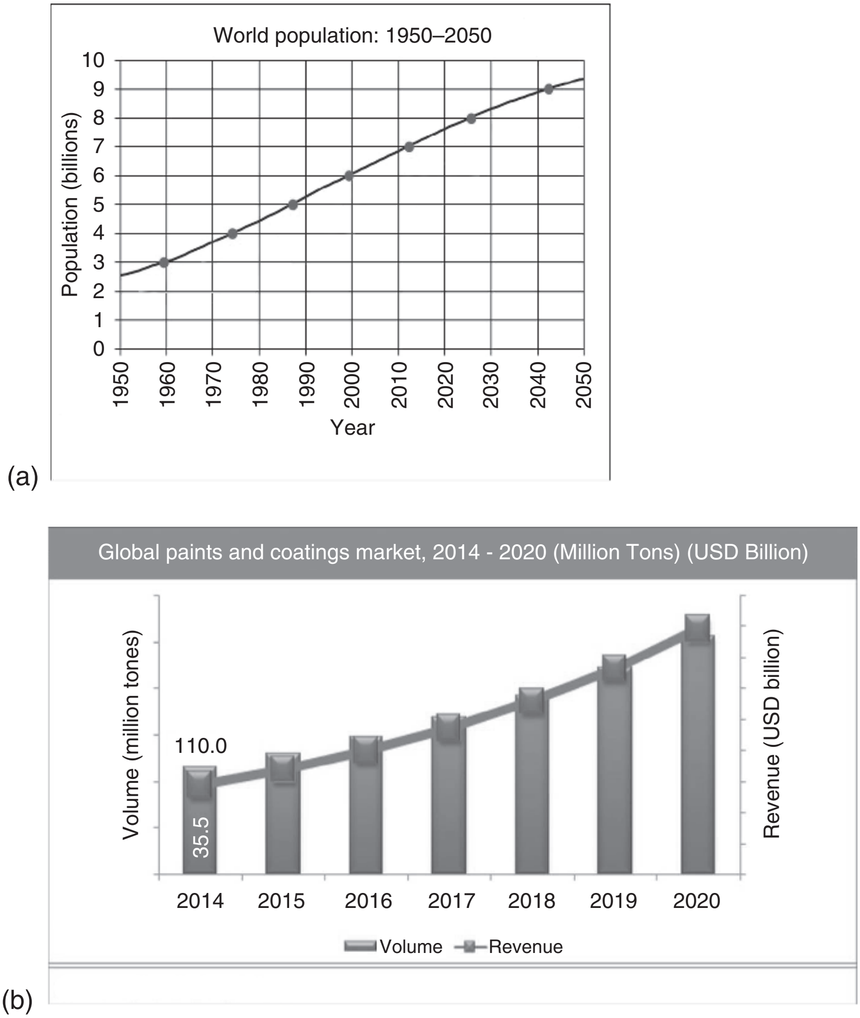

Figure 1.1 World population and coatings. (a) Growth of the world population [3] and (b) growth of the coating market [4]. Source: (a) U.S. Census Bureau, International Data Base, August 2016 update. (b) Zion Research Analysis 2015.

1.3 The General Constitution of Polymer Coatings

Typically, coatings formulations contain the following ingredients: binders, pigments or fillers, additives, and solvents. Table 1.1 provides an overview of their function.

Taken these components as granted, a wide variety of type of coatings can be discerned, and various classification schemes can be used. Considering the *volatile organic components* (VOCs), the most important types of coatings are:

- Solventborne coatings, 400–600 g l^{-1} VOC.
- High solids solventborne coatings, 200–400 g l^{-1} VOC.

Table 1.1 Coating formulation characteristics.

Nonvolatile	Volatile	Chemistry	Function
Binders	—	Polymers, resins	Adherence to pigments and substrate providing the base for the integrity of a film; protection of the substrate, e.g. against corrosion
Pigments	—	Insoluble solids	Aesthetic quality, e.g. color, opacity, or visual effects, and protection, e.g. corrosion
Additives	—	Inorganic/organic solids	Minor compounds, wide in variety and effect, e.g. flow agents
—	Solvents	Organic liquids, water	Facilitate paint application, e.g. by controlling viscosity
—	Additives	Organic compounds	e.g. dryers, UV-absorbers, defoamers

- Waterborne coatings (meaning water-soluble and latex-based), 0–100 g l^{-1} VOC.
- Powder coatings (both thermoplastic and thermosetting), 0–50 g l^{-1} VOC.
- Solventless liquid coatings, 0–20 g l^{-1} VOC.

Reduction of the amount of VOCs is an important driving factor for many coating applications.

1.3.1 Binders and Crosslinkers

The basic ingredients of coatings are the binders. *Binders* are usually polymers or resins with proper film formation as primary function, also providing the required mechanical properties of the coating, realizing good adhesion between coating and substrate, and offering sufficient resistance to chemical and mechanical damage. Both low (typically 10^3 D, high solids coatings) and high (typically 10^6 D, emulsion-based coatings, paints) molecular mass binders are used; see examples in Table 1.2.

Low molar mass binders normally require a further chemical reaction to realize a proper coating, while a further chemical reaction is not absolutely required for high molar mass binders to obtain good properties.

Several criteria are relevant for a proper choice of binder:

- Type of use: indoor or outdoor. Whereas outdoor coatings should be able to withstand degradation by UV radiation and water, for indoor coatings these requirements are virtually absent.
- Type of layer: base coat, topcoat, and so on. While a base coat is applied for mechanical reasons, a topcoat should be UV and water resistant.
- Adhesion, dependent on the type of substrate: metal, wood, glass, plastics, and so on.
- Requirements of target property: gloss, hardness, color, solvent resistance, corrosion protection, and so on.

Table 1.2 Typical binder compounds. Source: Lambourne and Strivens 1999 [5]. Adapted with permission of Elsevier.

Low molecular mass	High molecular mass
Alkyds	Acrylics
Polyesters	Vinylics
Polyurethanes	Nitrocellulose
Urethane oils	Styrene/butadiene
Amino resins	Poly(vinyl acetate), PVA
Phenolic resins	
Epoxide resins	
Chlorinated rubber	

In many cases nowadays combinations of the various chemistries, also named *hybrids*, are used, e.g. polyurethane–alkyds or polyurethane–acrylics.

- Application method[1] involved: brushing, spray drying, dip-coating, and so on.
- Health and environment considerations (constraining options via specific regulations and/or protocols).
- Price (in the end, coatings have to be produced and sold).

Although a part of coatings, in particular water-based paints, obtain their integrity by (physical) drying, that is, simply solvent evaporation, with many other coatings the integrity is only established after realizing a (covalently bonded) network. In that case one usually adds a *crosslinker*, that is, a relatively small molecule capable of reacting with an active group of the resins so that a polymeric network can be created, a process that is called *crosslinking* or *curing*. Typical examples are molecules with an amino, isocyanate, or a C=C functionality. Crosslinking is usually done using a thermal treatment. The thermal energy (heat) involved in curing constitutes a large part of the environmental footprint, and, hence, there is a drive to use an as-close-as-possible near ambient temperature. Alternatively, one can use radiation curing, and UV radiation is the most frequently used type of radiation so far. However, with the increasing availability of *light emitting diodes* (LEDs) with sufficient intensity and choice of spectral range, there is a recent drive toward daylight curing, thereby also increasing energy efficiency and safety of the process. As discussed in later chapters, it will become evident that each of these processes has its own advantage and disadvantage.

To achieve all the requirements of an application, often several layers are applied (Figure 1.2). The first layer is called the *primer* and seals the substrate from the environment, meanwhile providing good adhesion. The second layer is the *undercoat*(s), which provides some function and prepares for the topcoating,

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[1] In coating technology the deposition technique used is often addressed as application, although the intended use or purpose of a coating obviously carries the same designation. We will use application method and application field whenever confusion is possible.

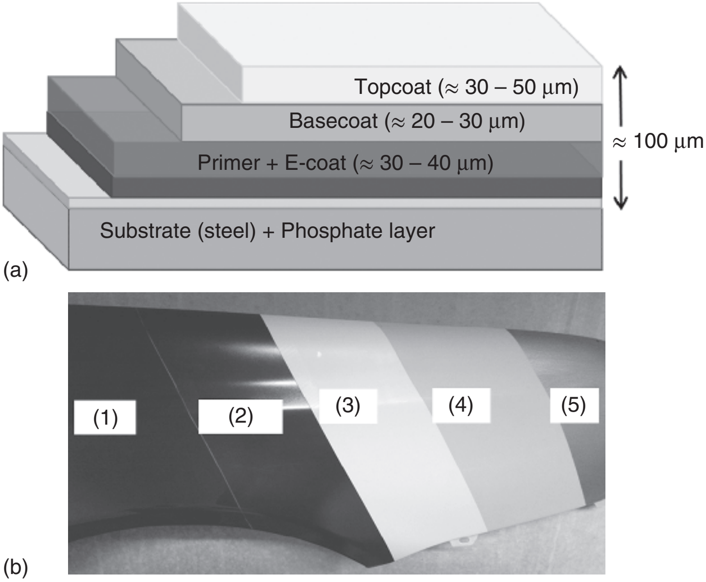

Figure 1.2 Typical polymer coating design. (a) Schematic of the buildup of several layers involved in typical automobile coating and (b) actual layer sequence on a car side panel showing (1) UV clear coat, (2) waterborne base coat, (3) filler, (4) wash primer, and (5) steel substrate.

while the third is the *topcoat*, also providing some functionality and aesthetic aspects. Typical compounds used in coating formulations are shown in Table 1.2.

1.3.2 Pigments and Fillers

Particulate components, that is, powder-like components, are added to most coatings typically for property enhancement, in particular for their optical behavior (color, opacity, gloss), their protective and reinforcing function (hardness, flexibility) and their anticorrosion function (using, e.g. sacrificial or conductive components). While in relation to optical behavior, these components are normally addressed as *pigments*, in discussing protection and reinforcement, they are often denoted as *fillers*. In some cases a component is used for more than one purpose, for example, silica particles can be used as matting agent as well as for the improvement of film hardness. Pigments are typically:

- White (>90%), colored, black, or fluorescent organic and inorganic particulate solids.
- Insoluble in the binder or solvent used.[2]
- Dispersed in the binder in case of solvent-based and solventless coatings.
- Physically and chemically unaffected by other coating components.
- Retain a crystal or particulate structure throughout the incorporation process.

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[2] Note that also soluble organic colorants are used, to which one usually refers to as *dyes*.

- Change coating appearance (e.g. by selective absorption and/or scattering of light).

The various types of pigments can be classified as:

- *Inorganic pigments*. For color one can distinguish between white and colored pigments. As white pigment one typically uses oxides, such as TiO_2 and ZnO, or sulfides like ZnS. Additionally so-called *extenders* are often used, typically sulfates, carbonates, or silica, primarily to reduce cost. For colored pigments, carbon black, mixed oxides (Fe_2O_3), and metallic flakes are often employed.
- *Organic pigments*. These constitute mainly colored pigments, of which azo-containing compounds are by far the most important, but also phthalocyanines are often used.

The performance of pigments depends not only on their optical properties (refractive index, selective absorption, etc.) but also on the particle size and shape and the state of dispersion of the pigments. Table 1.3 provides an overview of some typical pigment characteristics to take in account for a particular application field, while Figure 1.3 shows some examples of modern pigments and the effect or their agglomeration state on the final color properties.

Two parameters to take in consideration when using pigments in coatings formulations are the *pigment volume concentration* (PVC) and *critical pigment volume concentration* (CPVC). The PVC is related to the *pigment packing*

Table 1.3 Typical pigment properties.

Property	Inorganic pigment	Organic pigment
Solubility	Generally insoluble	Slightly soluble
Tinting strength	Low	High
Hiding power	High, opaque	More transparent
Specific gravity	High	Low
Heat resistance	High	Low
Intensity	Low	High

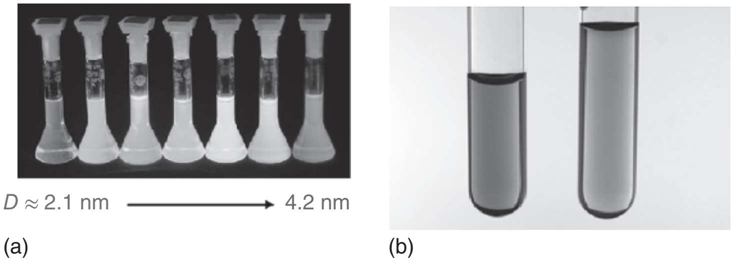

Figure 1.3 Examples of modern pigments. (a) CdSe nanoparticle suspensions, showing a color change with size variation, $D \approx 2.1\ \text{nm} \rightarrow 4.2\ \text{nm}$. (b) Left: individual gold nanoparticles in a citrate solution. Right: agglomerated gold nanoparticles after adding a NaCl solution.

factor ϕ. These parameters are given by

$$\mathrm{PVC} = V_p/(V_p + V_b) \quad \text{and} \quad \phi = V_p/(V_p + V_b + V_a), \tag{1.1}$$

where V_p is the volume of the particles (pigments and fillers), V_b is the volume of the binder, and V_a is the volume of void spaces (air). Evidently, for $V_a = 0$, $\phi = \mathrm{PVC}$, but for $V_a \neq 0$, $\phi \neq \mathrm{PVC}$. The properties of most paints are optimal at the CPVC because below that value particles loose contact and are separated by binder, while above that value binder is replaced by air. The CPVP is thus the maximum packing density of the pigment in the film, at which just enough binder is present to completely coat the surface of the pigment particles and fill all the void spaces between them. Beyond the CPVC, there is not enough binder to cover all the particulates and fill the voids; hence, some porosity will develop which has immediate and sometimes dramatic consequences on the properties of the coating; see Figure 1.4. The precise value of the CPVC depends on the particle size (distribution) and the shape of the pigment and filler particles.

As a guiding formulation principle, one uses as maximum value for PVC a value of ±5% around the CPVC value. Obviously here one has to accept a compromise depending on target applications. Topcoats with high gloss and low permeability typically require compositions below the CPVC, while under-layers and primers are often containing pigments and fillers beyond the CPCV. The determination of the CPVC level can be done by measuring, for example, oil absorption values using a specified linseed oil with an acid number about 2.8 mg KOH g^{-1} (for a review of CPVC measurements, see [8]). Figure 1.4 illustrates the film properties for a particular system as a function of the PVC [6, 7].

For the origin of color, one encounters a difference in mechanism for organic and inorganic pigments. For organic pigments *chromophores*, that is, specific groups of atoms that absorb light, are usually the determining factor. Typically

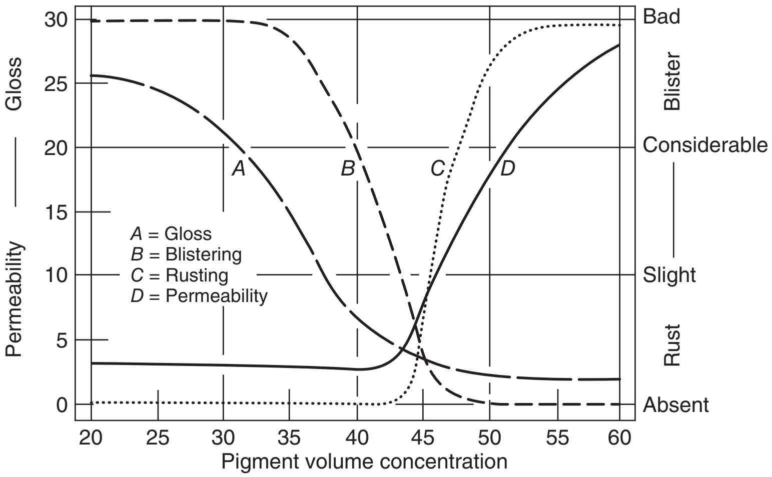

Figure 1.4 Various coating properties as a function of PVC [6, 7].

they contain aromatic rings. For about 70% of the organic pigments used in coatings, azo-aromatic compounds form the main constituents. For inorganic pigments the *electronic transitions* and *charge transfer* between molecular orbital energy levels are often determining. For example, CdS and CdSe are used for yellow and orange coloring, while $Na_{8-10}Al_6Si_6O_{24}S_{2-4}$ (ultramarine blue) is a typical blue pigment. A specialty pigment class is that of *fluorescent pigments*, in which charge recombination and return to low energy levels provide emission with a different wavelength (Figure 1.5a). Selective absorption and reflection of various wavelengths within the visible spectrum sees to it whether a pigment is a black pigment, absorbing all light from the visible spectrum (Figure 1.5b), or a white pigment, which scatters and reflects virtually all visible light wavelengths falling on their surfaces.

By far the most used white pigment is rutile (TiO_2), not only for its high hiding power due to its high refractive index but also for its UV-screening activity. This scenario is, however, most likely to change in the coming years in view of the very recent regulations on nanomaterials and specific concerns on the use of TiO_2 nanoparticles [9, 10].

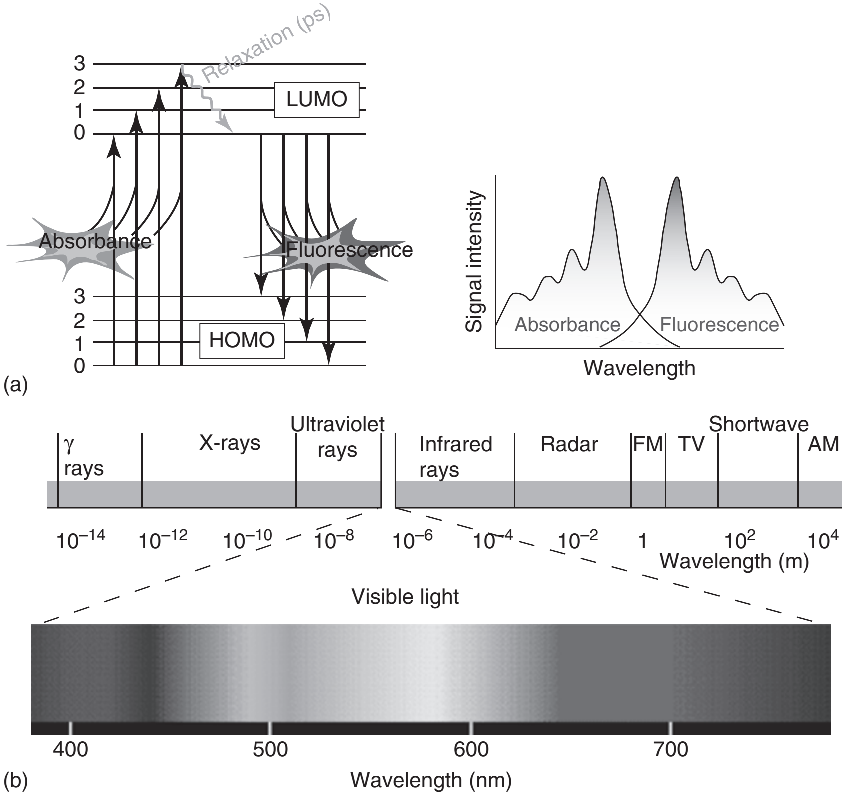

Figure 1.5 Optical effects. (a) Mechanism of coloration for fluorescent pigments and (b) the electromagnetic spectrum with the (enlarged) optical region.

For special effect coatings, such as coatings with the *mother-of-pearl* effect often used in cosmetics and *metallic lacquers* frequently applied on cars, one uses mica and Al flakes, respectively.

Apart from that, the color of pigments is also determined by the chemical nature (molecular structure), the crystal form, the particle size and shape, and the agglomeration state of the particles. An important criterion for colored pigments is high chromaticity, relevant for clean self-colors and color blending (see Chapter 11). in addition to a high ion, water (moisture) and erosion, and no degradation when in contact with other organic materials. Finally, pigments should also be resistant to processing chemicals (solvents) and heat.

1.3.3 Additives

Additives are used for property improvement and added for special purposes so that these constituents are often seen as *problem solvers*. It should be that even a very small percentage of additive in the formulation can have a strong effect. Furthermore, although specific components can be effective in one formulation, they might be ineffective in other formulation. They can also frequently give rise to undesirable secondary effects (in this respect, they are comparable to medicines). There is extensive and to some extent very specific literature available on additives for coatings [11], and it is therefore out of our scope to cover them exhaustively. Hence, herein we only mention a few categories most commonly present in coatings, such as thickening agents, surface active agents (influencing wetting, dispersing, foaming behavior, and adhesion), surface modifiers (slip additives, matting agents), leveling and coalescing agents, catalytically active additives (dryers and catalysts), and a brief reference to special effect additives (anti-skimming agents, light stabilizers, corrosion inhibitors, biocides, flame retardants, and photoinitiators).

1.3.4 Solvents

The main purpose of solvents is their use in production and application of the paint. They influence the processability, the film formation, and appearance of the coating. The role of solvents is than mostly *transient*, that is, they should evaporate, and they play an important role in binder solubility, miscibility, overall dispersibility, and stability of all the components, throughout the preparation of the formulation and also during storage. Of course, they are also important for coating application via their influence on the viscosity, drying, and film formation. *Reactive diluents* are solvents that are incorporated in the coating by a chemical reaction, thereby lowering the amount of VOCs.

Solvents may, however, lead to film defects, such as blistering, matting, sagging, and popping (Figure 1.6). *Blistering* typically occurs, either due to excessive film thickness, insufficient drying time between coats, or application of a too thick undercoat in which solvents entrapped will escape later and blister the over-coats. *Matting* can occur when, due to using an improper ratio between binder, filler, and solvent, particles agglomerate and cause excessive light scattering. *Sagging* is obviously due to an improper balance between viscous behavior

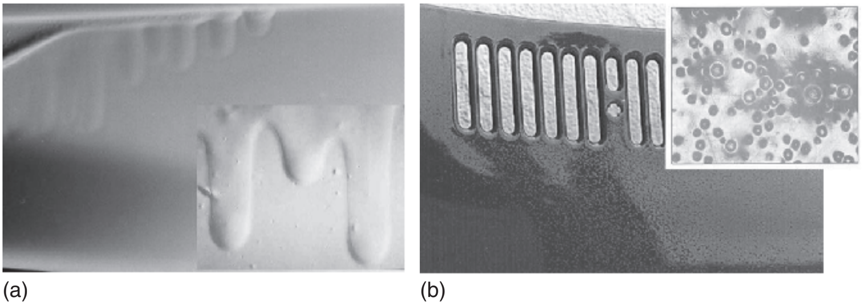

Figure 1.6 Defects in coatings. (a) Sagging and (b) popping.

and film formation. *Popping* occurs by evaporation of solvent from small solvent bubbles formed in the partially formed film so that leveling thereafter is difficult.

The final coating properties also depend on how the solvent evaporates, influencing the pigment, binder, and additive dispersion with an effect on the film appearance (homogeneity). The solvent evaporation rate controls the amount of solvent left, the viscosity, and the surface tension. Moreover, a binder composition that is initially within the solubility region for the solvent (mixture) chosen may move outside that region, and, depending on the various rates, phase separation may occur and lead to film defects. Other factors include the surface area available, the application method and heat and mass transport considerations. To avoid the introduction of defects, a proper rate of solvent evaporation is thus essential. Solvents typically show a *two-stage solvent evaporation process* (Figure 1.7a). The first stage is controlled by the solvent vapor pressure, where the main resistance is the thin stagnant air layer above the coatings surface. The second stage is controlled by the rate of diffusion of solvent through the, already formed, thin coating film to reach the surface (with below 20–30% remaining solvent). Obviously, the change of properties of a solvent mixture, as illustrated in Figure 1.7b [12], affects the final film properties.

In the past nearly exclusively organic solvents were used, with as notable exception, emulsion paints that were often water based. The wide variety of physical–chemical properties of solvents is summarized by Wypich [13]. Nowadays, water is becoming a more and more important medium, also for other types of coatings, mainly for environmental reasons. Hazardous solvents are listed in the hazardous air pollutants (HAPs) list [14] containing pollutants suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects (*organo-psycho syndrome* (OPS)) or adverse environmental effects.

In summary, the formulating methodology of solvents comprises establishing polymer solubility and miscibility formulation targets, specifying the evaporation profile and other properties of the solvent blend, formulating solvent blends that meet polymer solubility and other requirements and testing the resulting formulations experimentally to confirm predicted results. In view of their relevance several of these aspects will be addressed in detail in the following chapters.

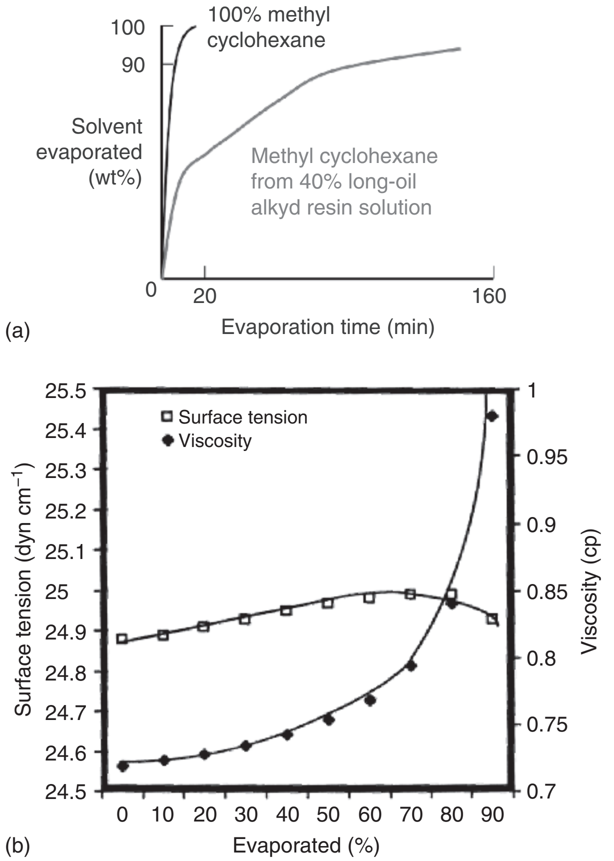

Figure 1.7 Changes due to solvent evaporation. (a) Amount of solvent evaporated as a function of time for a pure solvent and a solvent–resin mixture, showing multistage behavior, and (b) change in viscosity and surface tension of a solvent mixture as a function of percentage evaporation. Source: Paul 1995 [12]. Reproduced with permission of John Wiley & Sons.

1.4 Coating Requirements

Coatings do have various application fields with the three main purposes of protection, decoration, and adding functionality. Different application fields have varying requirements that can be divided in generic and specific ones. Generic aspects are independent of the field and apply to all types of coating. One example is adhesion, as the coating will not function if it does not adhere to the substrate, and this is true under all circumstances. Moreover, coatings have to be able to be applied to surfaces, and, hence, an aspect like wetting is also important for many applications. With respect to specific aspects, these are field dependent, but first and foremost, coatings still serve the purpose of being protective and decorative. Protection can mean different things in different circumstances. Indoor coatings generally experience limited UV radiation, making weathering much less important. On the other hand, for outdoor applications, such as automotive coatings, the weathering or environmental resistance is one of the most important issues. Other examples are electrically conductive coatings or optical/aesthetic coatings where gloss, transparency, and color dominate. However, generally multiple considerations play a role. That is, not only the primary function, be it protection, color, or conductivity, but also the other (generic) factors, like adhesion and durability, plays a role.

1.5 Outline and Approach

From this brief introduction to polymer coatings, it will be clear that it is fairly impossible to deal with all aspects in depth, and we will focus on the basics, dealing with the underlying theoretical concepts, and few modern applications, relevant for chemical engineers and chemists in average daily practice. Before elaborating somewhat on the content, we note that, possibly inevitably for such a multi-aspect field as polymer coatings, one uses frequently jargon, including different words for well-established concepts or materials (e.g. dryers meaning catalysts) and a multiple meaning for one label (e.g. there are two *telegraphing* effects and application denoting the deposition method and the use of a coating on a substrate).

The content is divided in two main parts. In the first part, containing Chapters 2–11, we deal with the basics. In Chapter 2 we provide a brief outline of network formation and thereafter discuss in Chapter 3 the binders in some detail, starting with petro-based chemistry and focusing thereafter on more modern developments. Chapter 4 provides an overview of various coating formulations. Additives are dealt with in Chapter 5, while Chapter 6 provides a discussion on application methods. Thereafter, in Chapter 7 we deal in some depth with a number of highly relevant physical–chemical aspects for polymer coatings, while Chapter 8 discusses chemical and morphological characterization methods. For coatings some other generic aspects are their thermal and thermo-mechanical behavior that are treated in Chapter 9. We end this part with Chapter 10, which provides a discussion on rheological aspects, and Chapter 11, which deals with appearance, that is, defects and color.

In the second part, containing Chapters 12–15, we deal with a few selected applications of coatings. Chapter 12 deals with electrically conductive coatings, for example, to limit electrostatic charging of electronic devices or as conductor. Fouling is a major point of concern for many coatings, and in Chapter 13 antifouling coatings are discussed with focus on marine applications. As said before, damages are inevitable in coatings; hence, it would be most advantageous to be able to recover properties after damage. Therefore an overview of self-healing coatings is given in Chapter 14, highlighting self-replenishing strategies to recover surface functionality. With this selection, applications are evidently not exhaustively treated. The present choice is, like the treatment as a whole, limited by the size of a book as well as limits of expertise. Therefore, in Chapter 15 an outlook is given about some promising coating aspects under investigation at present, a brief discussion on relevant topics not dealt with and possible future scenarios.

Each chapter contains, apart from specific references, a list of books entitled "Further Reading" that can be selected for further reading and are referred to by: author (year). Finally, for notation aspects, we refer to the symbols list.

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