

EUROPEAN COATINGS TECH FILES



Volkmar Stenzel | Nadine Rehfeld

Functional Coatings

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Foreword

Just about every article or object we encounter in daily life has a surface that has been treated in some way during its manufacturing process. The surface is what we first recognise when we see or touch an article or object. Surface treatment is responsible for the decoration, surface feel and protection of the surface, including corrosion protection. New developments (e.g. nanotechnology, encapsulation technologies, etc.) have opened up new opportunities for the integration of new surface functions, in addition to decoration and protection.

One of the best known functional surfaces is the surface of lotus leaves. These surfaces are extremely dirt-repellent due to their hydrophobic properties. A large amount of research is also being conducted on other, equally interesting surface properties, e.g. anti-fouling, drag-reducing, and self-healing, and is striving to transfer the underlying surface principles into concepts for coatings. Interdisciplinary work groups in research organisations and industrial companies are actively exploring the enormous potential of functional coatings.

This book summarises the vast number of new developments and the results of this work.

The present book gives users of paint technology an overview of the most promising developments and approaches. It also gives readers an idea of what is currently possible and what is likely to be possible in the near future. It highlights the current status of development or market introduction of the different technologies and novel surface functions that go beyond decoration, corrosion protection and surface protection.

We naturally had the difficult task of selecting information from a huge number of publications and we had to focus on the most important aspects for the users of paints and coatings, paint chemists, and paint manufacturers. We chose to focus on organic coatings (including organic-inorganic hybrid coatings) and have not addressed PVD/CVD methods, galvanic methods and other non paint/lacquer related topics.

Bremen, Germany in October 2010

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Corrosion

in Quick-Motion



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Nanotechnology

The reader will receive an overview of coatings systems based on the application of chemical nanotechnology. Practitioners will be given an introduction to nanostructured coatings and experts will find the account of various silane-based materials useful.



» **Nanotechnology**
Stefan Sepeur et al., May 2008,
168 pages, hardcover
156,- €
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1 *Introduction*

The term “functional coating” has been widely used in recent years and is a buzz-word, as were “nano” and “bio” previously. Accordingly, a very large number of scientific papers have been published that present old and new approaches to functional surfaces and describe a huge number of potential applications for functional coatings.

What, though, do we mean by “functional coating”? There is in fact no general definition for this term. According to DIN EN ISO 4618:2006 a coating is in general a “...continuous layer formed from a single or multiple application of a coating material to a substrate”. Furthermore, a coating material is defined as a “...product in liquid, paste or powder form which, when applied to a substrate, forms a film possessing protective, decorative and/or other specific properties”. Functional coatings have special properties and so give the surface new additional functions. This meaning of the term is reflected in the content of this book.

So how can we utilise the great wealth of information? We chose to focus on organic coatings (including organic-inorganic hybrid coatings), and present the most important aspects for the users of paints and coatings, paint chemists, and paint manufacturers. It also gives readers an idea of what is currently possible and what is likely to be possible in the near future. It highlights the current status of development or market introduction of the different technologies and novel surface functions that go beyond decoration, corrosion protection and surface protection.

1.1 *Motivation*

Surface technology is used in all goods-producing sectors of industry. The added value from surface technology is approximately 3 to 7 %. Surface treatment, coating, and finishing usually focus on necessary functions such as corrosion protection, decoration, design, and surface protection. Additional surface functions can create additional value for industrial products, but what are the most important functions and which are most desired?

In order to answer these questions, the German Society for Surface Treatment (Deutsche Gesellschaft für Oberflächenbehandlung e.V.) carried out a survey (“Forschungsagenda Oberfläche”, DFO Service GmbH, Neuss, 2007) to identify the needs of German industry in the area of surface technologies. More than 300 technical experts from about 100 companies, 30 institutes, colleges etc. and several industrial associations participated in this survey. Despite the fact that the survey only covered Germany, we believe the results also apply to most other advanced industrial countries.

From the many (more than 100) technical topics and ideas that were signalled by the survey, 3 clusters were formed:

- knowledge-based quality improvement
- efficient processes
- multifunctional surfaces

From all the topics that were indicated, nine so-called flagship topics were identified. These flagship topics represent the research areas which are thought to have the highest impact on the competitiveness of manufacturing industry. The flagship topics were defined taking particular account of economic, environmental, and social sustainability.

The flagship topics are as follows:

- **active layers** (e.g. photovoltaic technology, catalytic surfaces)
- **switching surfaces** (e.g. switching between hydrophobic/hydrophilic behaviour, colours, electrical conduction/non-conduction)
- **anti-fouling surfaces** (e.g. lotus effect, photocatalytic self-cleaning, non-toxic maritime anti-fouling)
- **self-repairing surfaces** (long-term surface protection, e.g. wind turbines, heavy-duty corrosion protection)
- precision manufacturing via model-based control and regulation
- digital factory
- **hybrid materials with complex morphology** (e.g. anti-reflective glass coatings)
- rapid testing for degradation and corrosion
- **brand protection**

The bold letters indicate topics that are of relevance for the development of functional surfaces.

Further important findings of the survey were:

- The added value of surface and coating technology in Germany amounts to about 20 billion Euros per annum.
- Higher added value due to the introduction of new surface functions can considerably increase competitiveness. It has been estimated that a 5 % increase in added value due to innovative surface technology compensates a 20 % lower cost of manufacturing in foreign countries.

These two findings are motivation enough to be engaged in the development, manufacturing and selling of products with functional surfaces.

1.2 Content and aim of this book

This book outlines recent developments in the field of functional coatings, with the focus on organic-based materials. The first part describes so-called toolbox methods which are currently available to developers. These cover a large number of methods, ranging from the manufacture of specific topographies on the microscale and nanoscale to the use of microcapsules and nanoparticles, and customised surface immobilisation of molecules. The functionalities themselves are at the fore in the second part of this book. These can, for example, be structure-based (e.g. drag-reducing) or chemical-based (e.g. self-healing) and can be produced via very different routes (e.g. anti-fouling, anti-icing).

It is important to stress that most of the examples described here are not yet ready for widespread industrial implementation. Indeed, the functionalities that are described are at different stages of development. Some merely represent promising first laboratory results (e.g. surface binding of anti-freeze proteins), others are at the production concept stage (e.g. paint structuring for drag-reducing surfaces), and some are already in use (e.g. self-healing car lacquer systems). The book gives an indication of the stage of current developments in the area of organic-based coatings and what future technical applications can be expected.

2 *Tool-box*

2.1 *Paint surfaces with defined microtopography and nanotopography*

The topography of a surface plays a major role in determining a variety of properties of that surface. Besides obvious properties such as the degree of gloss/mat, others such as wettability, drag, adhesion, and light reflection are highly influenced by the surface topography. This fact can be utilised in order to generate functional paint surfaces. Indeed, nature has utilised this for millions of years, as illustrated by the following examples.

2.1.1 *Examples from nature*

Nature displays a wealth of different surface topographies in plants and animals, giving rise to surfaces having specific functions (see also Chapter 3.6). The fact that nature displays a great variety of functions via the creation of microstructures and nanostructures on surfaces demonstrates that there are opportunities for developing surfaces with similar functions for technical applications. Examples of natural functional surfaces based on microstructures and nanostructures are described in the following.

Lotus leaf

The self-cleaning effect of the lotus leaf^[1] is certainly the best known example of a natural, functional surface. The same effect also occurs in other plants, for example lady's mantle and kohlrabi (albeit "kohlrabi effect" would sound far less interesting than lotus effect). The effect is based on chemical hydrophobisation due to secreted waxes coupled with a microstructure and nanostructure (for mechanism see Chapter 2.1.2).

Skin of fast-swimming sharks

Decades ago it was observed that the scales of fast-swimming species of sharks have parallel riblets in the direction of flow around of the body. It is now known that this microstructure reduces the drag of the water by a few percentage points and so helps the shark save energy for motion (see Chapter 3.4).

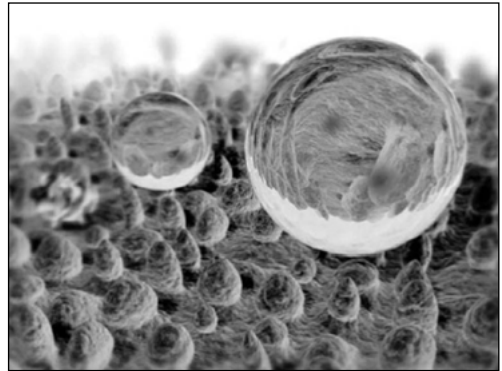


Figure 2.1: Surface of a lotus leaf (computer animation)
source: S. Sepeur^[2]

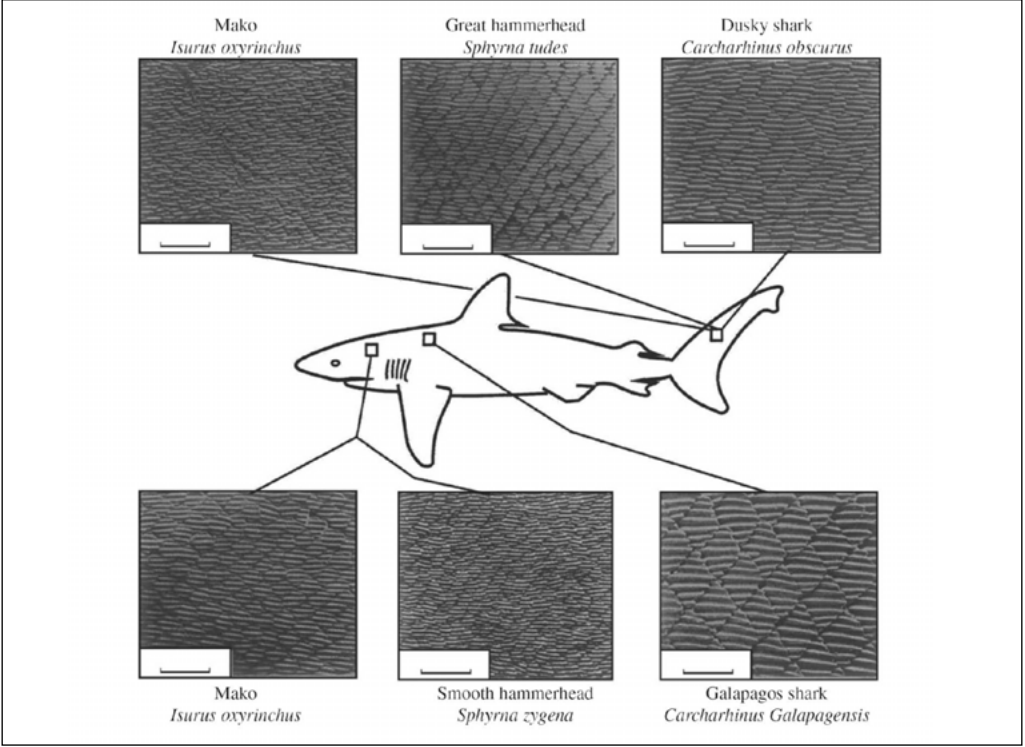


Figure 2.2: Surface structures on fast-swimming sharks ^[3]

source: Wolfram Hage, DLR

2.1.2 Influence of surface topography on wetting

The wetting properties of a surface are very important for many surface functions. For example, the wetting properties very much determine the soiling, easy-to-clean properties, ice formation and adhesion, ability to be coated, and drag (in water). The surface topography at the microlevel and nanolevel in turn has a big influence on the wetting. For this reason, it is worth exploring the relationship between topography and wettability at this point in greater detail.

2.1.2.1 Ideal surfaces

The ability of a liquid to wet a smooth surface can be determined, for example, by measuring the contact angle. This is done by placing a drop of liquid on the surface and measuring the contact angle at the solid-liquid-air (or vapour) phase boundary using a special microscope (see Figure 2.3).

The contact angle of a liquid on a surface depends on the relationship between the surface energies (= surface tensions) of the relevant phases at the drop boundary (solid, liquid, gas). The relationship for an ideal smooth and homogenous surface is described by Young's equation ^[4]:

$$\text{Equation 2.1} \quad \cos \theta = \frac{\gamma_s - \gamma_{sl}}{\gamma_l}$$

where γ_s is the free surface energy of the solid, γ_l is the surface tension of the liquid, and γ_{sl} is the interfacial energy between the solid and liquid.