1 Introduction

1.1 Definition, Tasks and Economic Importance

The task of coating technology is to provide surface protection, decorative finishes and numerous special functions for commodities and merchandise by means of organic coatings. Many everyday products are only made usable and thus saleable because of their surface treatment. To achieve this, relevant coating formulations, their production plant, the coating material and suitable coating processes for the product must be available. However, the quality to be achieved by means of the coating process is not the only function of the coating material used. The object to be painted or coated itself with its specific material and design and an appropriate application process are further variables which play a significant role. In addressing the ongoing tasks of quality optimization and rationalisation while minimizing the impacts for humans and the environment, it is vital that the dependencies mentioned above be not only recognized but also taken into account as the framework defining the conditions in which work is carried out from development to application. Coating technology, therefore, is an interdisciplinary subject. Paints and coating materials are not end products, but merely initial or intermediate products which, for the above mentioned reasons, require a skilled and conscientious user if they are to be converted into the actual end product, the coating itself. Only the cured coating, in many cases a system consisting of several individual coats, may meet the wishes invested in and the requirements demanded of the coated products.

Two of the most important of the many functions which coatings have to meet are protection and decoration. Other noteworthy features are the informative tasks and the achievement of special physical effects. The conspicuousness of emergency service vehicles, the camouflage of military equipment, and road or airport markings are just some of the informative tasks required of coatings. Color markings enable areas or spaces to be clearly signed or divided. Color coding helps to indicate the contents of containers or the material being conveyed in pipes. Optical effects induced by colored or metallic pigments lend a coating a particular optical attraction. Deliberately generated surface textures such as scars or wrinkles expand the range of effects which can be achieved. The use of color schemes for rooms and machines based on known physi-
ological and psychological effects of colors also contributes in various ways to improved working conditions and enhanced safety. Functional pigments produce temperature dependent colors, for example as a result of their thermochromic properties, and therefore, indirectly permit the temperatures of objects to be measured.

The most important task for coatings, in economic terms, is surface protection. Thus coatings help to retain value and improve the usability properties of almost all products and are therefore, of huge economic significance. Particular mention should be made of the protection of goods made of metals which only gain lasting anticorrosive protection when they are painted.

It is vital in this regard, for example, in the automotive sector, for the resistance of the coating system to external, sometimes aggressive natural and anthropogenic atmospheric influences such as tree resins, bird droppings, acids, alkalis, salts and organic solvents, to be guaranteed.

The protective function of paint on cars must not be impaired even under extreme mechanical impacts such as stone chippings thrown up from the road by traffic or by brush action in carwashes.

Furthermore, coatings must withstand combined, i.e. physical and chemical, effects to which objects are subjected, for example, in the different weather conditions. The interaction of sunshine, rain, heat and frost combined with emissions from heating systems and internal combustion engines, by ozone and saline fog makes great demands on a coating’s resistance and protective properties.

However, a surface protection coating can also be applied in order to meet quite different requirements. Floors and steps can be made nonslip by means of rough or high grip coatings, thereby increasing their utility value. By contrast, surface friction can be reduced by use of smooth coatings to produce a high degree of nonadhesiveness. Flammable materials can be rendered safe by means of flame retardant coatings. Antibacterial coatings help maintain sterile surfaces in production and storage facilities in dairies and breweries or prevent the growth of barnacles and algae on ships’ hulls. In the electrical engineering sector insulating coatings provide effective and lasting insulation for wire, windings and condenser materials. On the other hand, conductive coatings can be used to make insulating substrates electrically conductive or even to print electrical circuits. Furthermore, organic coatings can help to reduce noise pollution. Acoustical insulation coatings for machines and underbody protection coatings for passenger cars are examples of this.
This broad spectrum of requirements explains why no single coating material can satisfy every wish simultaneously and in the same way. The goal of providing coating materials for the durable protection, decoration and improvement of objects made of wood, metal, plastic or mineral materials at reasonable prices can only be met by adopting different formulations using a range of materials and material combinations. Each of these combinations targets a limited field of substrates, a selected application method and a specific profile of film properties.

Coating technology is used in metal processing, in the manufacture of plant and machinery and in the electrical engineering industry. All kinds of road and rail vehicles, ships and aircraft are important objects which require painting or coating. Effective surface protection by means of paints and coatings is also indispensable in the civil engineering sector, for steel and concrete structures and in wood processing. Even plastics and leather require coating in many cases. Modern paper, plastic or sheet metal packaging materials are inconceivable without the protection and decoration afforded by coatings.

The worldwide paint and coatings market reflects economic developments in the regions. It is most highly developed, for example, in the so called triade (North America, Europe, South East Asia). The per capita consumption of paints and coatings in these regions is approx. 4.5 kg. The growth in coating consumption is determined by the economic development in the individual regions or countries [1.3.1].

The broad field of applications for coatings and their widespread use are explained by the high value and great benefits which they offer. The fact that there are few objects which do not require coating is an indication of the enormous importance of coating technology. Calculating this importance merely in terms of the quantity of coating materials manufactured annually worldwide of 28.6 million tonnes in 2006 with a value of some 80 billion euros (fig. 1.1.3) gives an incomplete picture.

Although quoting the quantities of coating materials is not a direct indication of the added value of industrial commodities, it does permit the area which can be protected or decorated by means of coating materials to be calculated, taking due account of the film thickness to be applied. Assuming an annual production quantity of 28.6 million tonnes and a wet film thickness of 100 µm (0.1 mm), a surface area of some 315,000 km² can be coated. That represents about 3/4 of the surface area of Germany. A 10 m wide strip with a film thickness of 100 µm, on the other hand, coated using the same quantity of paint would stretch about 100 times from the earth to the moon or go round the world 600 times.
A more meaningful means of evaluation would be to use the value of the effectively protected and improved products. Assuming that an added value of 20% of the produced goods is achieved by painting or coating them in the form of an extended service life and increased attractiveness, this means EUR 200 billion for the German market in 2000. This represents 50 times the sales value of the paints and coatings.

The division of the market into branches or segments is not uniform around the world. A number of breakdowns, however, seem agreed on using certain segments, such as decorative paints, general industrial paints, automotive paints, and printing inks.

Decorative paints represent the largest market for paints and coatings at 53%. This is followed, at 29%, by the market for the industrial coating of a huge range of objects, from compact discs via plastic bumpers for cars to rail vehicles (see chapter 7). Automotive coating lines and refinishing bodyshops are each clearly defined segments with a high technological value, though of less significance in terms of volume sales. Printing inks represent approx. 4% of the worldwide demand for coating materials and are a separate segment in technological and marketing terms, though not from the point of view of their composition.

The size of the European market was 9.1 million tonnes in 2006. There is a slight shift towards industrial coatings and printing inks compared with the sectoral division in the rest of the world. Germany is the leader with a consumption of approx. 1.6 million tonnes ahead of Italy, France, the UK and Spain, which are all in the range between 0.7 and 0.8 million tonnes. The size of the Northamerican market was 21.2 Bio. US $ in 2002 served by about 835 companies [1.3.2]

The graphic below gives an overview of the economic development of the paint and coatings industry in Germany since 2000 which is closely linked to the country’s overall economic development.

One of the characteristic features of coating technology in addition to coating consumption is the still high energy consumption for processing coatings which is estimated at approx. 200 billion kWh annually worldwide. This figure is the equivalent of the energy content of approx. 30 million tonnes of crude oil. If the raw materials required for paint production are also added to this figure in the form of crude oil equivalents, the result is a total crude oil requirement of approx. 100 million tonnes for the worldwide manufacture and processing of coating materials, or some 3 to 4% of the annual crude oil extraction worldwide.

The legal requirements imposed on environment compatible coating processes have resulted in greater use of appropriate coating materials in the last 20 years. These include, in particular, solvent free powder coatings, waterborne paints, in which organic
solvents are replaced in whole or in part by water, high solids paints and radiation curable paints, which are processed either in an aqueous solution or completely without conventional solvents with the aid of low molecular reactive thinners (see chapter 5). Statistics from the Association of the German Paint Industry (VdL) show that these coatings have achieved the greatest growth, with a 10% annual increase in the last 10 years.

Ongoing improvements in our knowledge of the toxicology of the raw materials entail a regular replacement of raw materials, which is associated with the corresponding development costs, if we wish to maintain the quality standard achieved.

As far as energy consumption is concerned, there is still a need to be more economical in the use of raw materials and energy. A proportion of the material is lost en route to the finished coating. Spray application, which is specified for many objects to be painted because of its optical attractiveness and range of colours, has a particular role in this regard. As far as coating wood and plastics is concerned, the more effective electrostatic spray methods have not yet found universal acceptance. In addition, the paintlines lose substantial quantities of heat energy. In recent years a number of developments have increased the efficiency of coating processes to such an extent that growth in the paint and coatings market in the industrially developed countries has been below the growth level of the gross domestic product (GDP).

As a result of the use of solvents as an application aid for coatings, an additional hydrocarbon emission load of approx. 200,000 tonnes is estimated annually in 2007 for Germany alone for the currently standard average organic solvent content of 50% [1.3.3]. Whereas the organic emissions from motor vehicles have been successfully reduced to less than 1/3 of their previous level in the last 20 years by the introduction of the catalytic converter, the successes in coating technology have been more modest to date by comparison. Despite the introduction of waterborne paints and powder coatings, approximately half of all the industrially processed coating materials used in Germany are still in the form of conventional, i.e. solvent-based materials.

From a European perspective, the solvent processing industries, including the paint and coatings industry, are now the leading emitters of organic compounds and solvents. European legislators responded to this fact by issuing a 1999 EU directive (see chapter 5.3) in an attempt to force even small to medium sized companies to adopt more stringent measures to avoid emissions.
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Significant success has been achieved by manufacturers and processors of paints and coatings with regard to occupational health and safety. The chemical industry, for example, has led the accident statistics in Germany for the industry with the least number of incidents.

An analysis of this situation reveals that manufacturers and consumers of paints and coatings, though occupying different value added stages, are extremely closely connected. Manufacturers develop and supply coatings materials to the consumers who in turn modify the product while processing them in physical, physico-chemical and chemical processes and convert them in this way into a bound, mechanically solid and, at the same time, flexible coating.

The path of chemistry from the raw material to the finished coating starts at the raw materials or paint manufacturer and is then consciously interrupted before it is taken up again during processing by the paint consumer.

Although the performance profile of a coating is initially shaped by the paint and thus by the paint manufacturer, it is the processor who actually generates the finished properties. The industrial scale coating of consumer goods is therefore a joint effort between paint and coatings manufacturers and processors.
Paint manufacturers who really know their job are nowadays responsible not only for developing, manufacturing and selling paint. Their task also includes providing the conditions for successful painting by their permanent technical presence and support. This relates primarily to materials and processes, though includes detailed environmental protection and occupational safety issues. Paint manufacturers offer a package, as it were, in which the material is just one component among many (see fig. 1.1.7). Apart from the technical tasks of manufacturing and processing coating materials, particular attention has to be paid to quality assurance methods. Quality assurance links production with R&D and sales within a company. Production must be capable of reproducibly providing the quality demanded by the customer, while sales must identify the total costs to achieve the appropriate prices.

However, paint manufacturers are faced with specific problems since they are expected to produce constant material quality and at the same time paints with constant processibility. Only this provides the best conditions for achieving a uniform result in the painted article. This means that production paint and coatings entails more than merely manufacturing a product whose composition is identical to a defined standard. Rather, since physical variables can only rarely be applied as criteria for the practical properties of coatings, paint testing of necessity includes simulating the application method used by the processor of these materials. This gives rise to a large number of different test methods because of the very wide range of specification conditions and the different requirements on the coating process resulting from them. Standardising these tests and reducing their overall number is also a priority task for all concerned.

Quality and costs of a coating are defined, as mentioned earlier, not only by the paint material and an application method appropriate to it, but also and significantly by the substrate, i.e. by the material and the design of the object to be painted. It is therefore clear that it is extremely important to address surface treatment, material selection and its design properties during product design and to integrate these features in the overall planning.

Coating technology is therefore a complex marriage of chemical, physical, process-engineering, environmental, toxic and economic variables. This discipline is in constant move as a result of technical progress and further accelerated by legislative requirements. Companies are therefore called upon to link well known features with new knowledge. Industrial coating technology can only be fully understood if, in addition to detailed knowledge of paint processing, the properties of the coating material and of the object to be coated are known as well and also if all the quality shaping variables within the range of economic and environmental requirements are addressed.