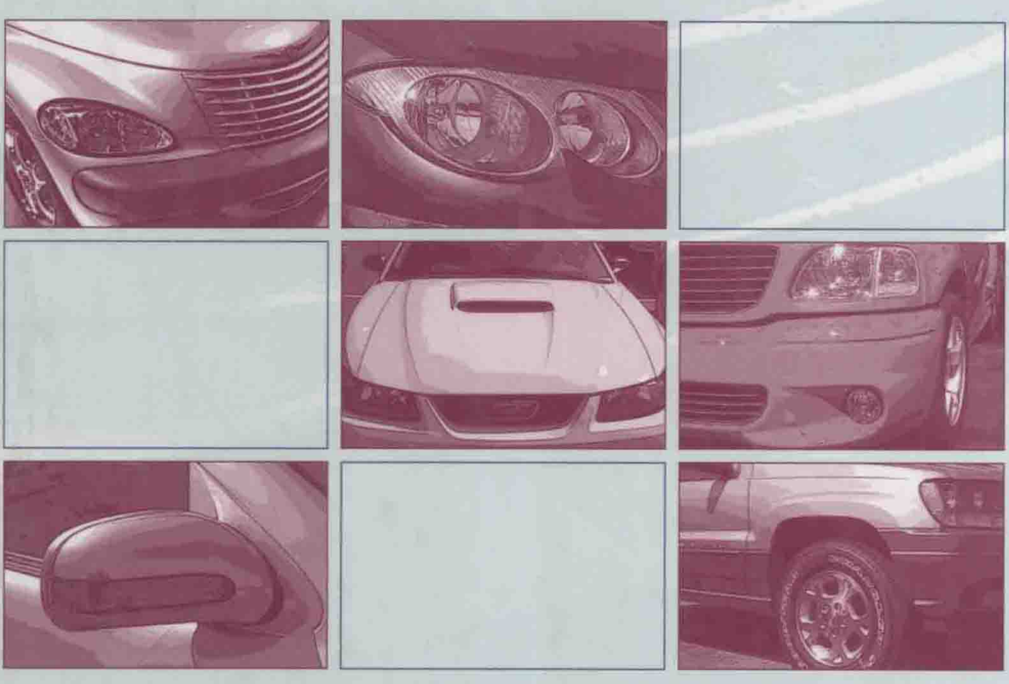
Coatings of
Polymers and Plastics



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To Thomas Yaneff,
who passed away during the production of the manuscript
and constantly encouraged and supported its writing and publication.

Preface

As a group, plastics are seeing increased widespread usage on a global scale. They continue to proliferate and dominate many industrial applications at ever-increasing rates. The shift from metal to plastic offers many advantages such as light weight, ease of formability, and low cost. While new types and grades of plastics emerge, many new and exciting challenges are introduced for the coating formulator and, ultimately, the part decorator. Adhesion and painted-part performance require attention to the smallest detail, from dispersion techniques utilized in formulating the resins to molding protocol utilized to fabricate the component, to paint type and application methods utilized to decorate the component, to service-life durability and performance, and finally to reuse or recyclate technologies utilized to alleviate land filling.

This book is directed toward both scientists and technologists working in the field of coatings for plastics. Chapter 1 begins with an extensive discussion on the types of plastics in use today and references the future needs and types of characteristics required to lower costs and enhance performance. Chapter 2 is then devoted to plastics processing requirements, which discusses molding parameters and the tooling needed to produce aesthetically pleasing and performance-capable parts.

Adhesion and the formulation tools required to achieve adhesion are discussed in Chapter 3, in the context of low surface free energy plastics, e.g., olefins. The ability to enhance adhesion as well as the possibility of increasing paint transfer efficiency, e.g., conductivity of the part, are discussed in subsequent chapters. Alternatives to paint are also addressed, in Chapter 8, particularly with respect to the need to achieve lower-cost, more environmentally compliant technologies.

Once a plastic part is decorated, issues centered on dirt and paint defects are addressed from the analytical point of view, and suggestions are made in Chapter 6 on how to identify and alleviate these defects.

We address an ever-increasing priority in Chapter 7—that of plastic part recycling and reuse once parts have reached the end-of-life cycle. The ability to remove paint is discussed in terms of process and performance. The ability to compatabilize dissimilar materials in lieu of the complexity of plastic families utilized industrially is also addressed.

Future trends in European and North American plastics markets are addressed in Chapters 9 and 10 from a product-life-cycle perspective. Specialized needs of the market or customer as well as environmental legislation, end-of-life requirements, and projected technologies required to achieve the proposed targets are introduced.

This book was born out of the perceived need for a comprehensive work to address decorated plastic components as systems rather than as independent parts. The interplay of resin chemistry, processing technology, and decoration scheme is a complex mix of interrelated events. Treating each event separately often leads to insurmountable issues, from potential decohesion of the plastic to potentially aesthetically displeasing appearance, and even to potential adhesion problems in the field. We hope that by addressing the overall manufacturing processes required to produce decorated plastic components as a system, we can begin to explore the possibilities of expanding the role of plastic in the industry. By improving overall performance of these materials there is no end to the possibilities of applications in which plastics can be utilized.

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Overview of the Automotive Plastics Market

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1 PLASTICS MARKETS

Human development is clearly linked to continuous improvements in the materials used every day. Entire stages of history have been named after the critical materials—Stone Age, Bronze Age, Iron Age, and now, the Age of Plastics. When asked his opinion on chemistry's largest contribution to science and society, Lord Todd, the President of the Royal Society of London, responded: "I am inclined to think that the development of polymerization is, perhaps, the biggest thing chemistry has done, where it has had the biggest effect on everyday life. The world would be a totally different place without artificial fibers, plastics, elastomers, etc. (1)."

Indeed, polymeric materials are ubiquitous in nearly all societies, with over 126 million metric tons consumed during 2000 (2) in the combined durable and nondurable markets. The range of unique combinations of performance characteristics, in comparison to metals and ceramics, presents both a significant value in well-established markets, as well as a host of new opportunities in emerging markets with demands that cannot be met by traditional materials.

Figure 1 shows the relative global consumption of major polymers. Polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC) represent over 80% of the global total volume, primarily because of their dominance in packaging and building and construction markets. However, engineering thermoset and thermoplastic polymers also offer outstanding performance in certain demanding

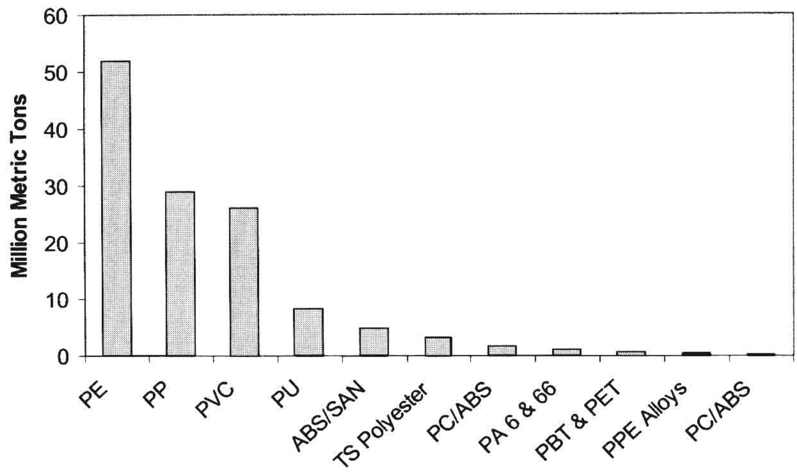

FIG. 1 Global consumption of major plastics in 2000. (From Ref. 2.)

durable goods applications, and thus also enjoy a significant global volume. The engineering plastics include polyurethanes (PU) and polyurea; acrylonitrile/butadiene/styrene (ABS) and styrene/acrylonitrile (SAN) copolymers; polycarbonates (PC); polyamides (PA); and polybutylene terephthalates (PBT) and polyethylene terephthalate (PET) polyesters. As replacement for metals, they offer the combination of inherent corrosion resistance and high strength. Examples of such applications include fencing, park benches, and automotive fuel tanks and exterior components.

Both durable and nondurable applications often require the plastics to be either printed or coated. As such, the interfacial characteristics of the plastic and the particular ink or coating are typically of concern during initial material selection and system design. While this book focuses on the coating of polymers, many of the principles discussed are also applicable to printing on plastic substrates.

Coatings are used because they efficiently impart a host of desirable features to substrates, such as enhanced aesthetics, greater barrier to moisture and chemicals, improved resistance to weathering and surface damage through physical impact, and certain specialty characteristics such as electrostatic dissipation. One example is polycarbonate optical discs, which are used as digital video discs (DVD) and compact discs (CD), and which are sputter coated on one side, typically with aluminum, aluminum alloys, or gold. These thin metal coatings are covered with an ultraviolet (UV)-cured, clear, acrylic coating that provides protection from the chemical and physical assaults of the environment. Another example is the PET bottle, which is coated with plasma-deposited SiO_2 and other SiCO barrier coatings to prolong the shelf life of its contents.

Because the coating of plastics is often driven by the need for excellent appearance and enhanced performance under extended use, durable goods by definition are overwhelmingly the substrates that can bear the burden of this additional cost. Thus, the use of coated plastics is very important in the automotive market in which the performance demands are high, and their maintenance throughout the vehicle lifetime is paramount.

1.1 Automotive Plastics Markets

The automotive industry exploits the entire range of performance characteristics offered by many polymer and plastic families. Table 1 lists the major plastics currently used in this market. Elastomeric and cellular materials provide comfort in seating systems, cushion the ride by dampening vibrations from the powertrain and suspension, and absorb and dissipate impact energy. At the other end of the performance spectrum, structural plastics and composites are the lightweight alternatives to metal that provide load-bearing body structures and help the industry meet stringent requirements for lower emissions and higher fuel economy. Plastics also allow cost-reducing consolidation of parts and function compared to assembled, multipart metal components, and provide desirable fea-

TABLE 1 Major Plastics Used in Automotive Applications

Polyethylene (PE)
Polypropylene (PP)
Polyvinyl chloride (PVC)
Polyurethane (PU)
Polyurea
Acrylonitrile/butadiene/styrene (ABS)
Styrene/acrylonitrile (SAN)
TS polyester
Polycarbonate (PC)
Polyamide (PA)
Polybutylene terephthalate (PBT)
Polyethylene terephthalate (PET)
PPE alloys
Unsaturated polyester resins (UPER)
Polyphenylene oxide (PPO)
Acrylic
ASA
AES
Polyphenylene oxide/polystyrene (PPO/PS)
Polyphenylene oxide/polyamide (PPO/PA)

tures such as complex styles and noise reduction while employing relatively simple manufacturing processes.

Selection of the appropriate polymer for an automotive application is based on functional considerations such as cost, density, chemical resistance, weatherability, recyclability, ease of processing, as well as the significant physical requirements of impact, strength, and stiffness—all of these over the anticipated range of use temperatures. For exterior applications, these temperatures can cover a large range, typically from sub-zero to the maximum temperature of an object heated for long periods of time in the blazing sun of a dessert (as high as 100°C).

The global automotive market consumed 5.6 million metric tons of major plastics during 2000, with thermoplastic olefin (TPO) elastomers as the dominant material (Fig. 2). Although this automotive volume is only about 4.4% of its global total across all applications (2), it represents 115.6 kg (254.3 lb) of plastics per each light-duty vehicle manufactured in North America, according to data generated by Market Search Inc., in their *Automotive Plastics Report–2000* (Fig. 3), and illustrates the intense drive of this industry to combine low cost with performance (3). Figure 2 also highlights the emphasis on engineering plastics in the automotive industry compared to the global market, in which polyolefins decidedly dominate.

Figure 3 shows that PP and PP blends (TPO) are the highest volume materials in the important light-duty vehicle (cars, vans, pickup trucks, and sport-utility vehicles) market in North America. This ranking reflects the signifi-

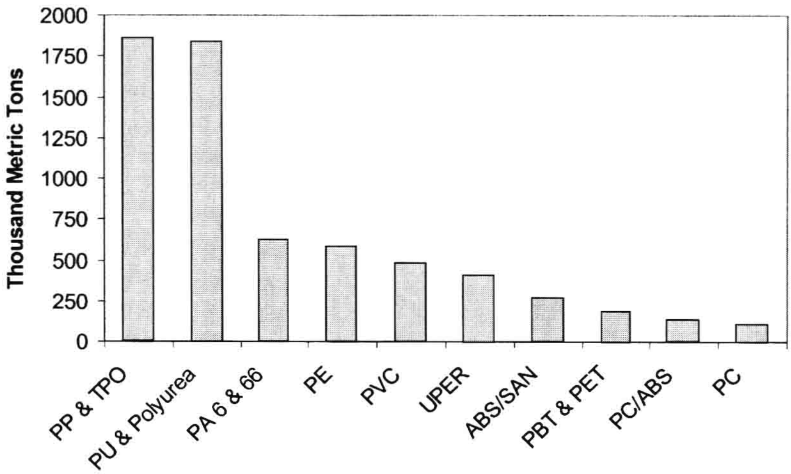

FIG. 2 Global consumption of major automotive plastics in 2000. (From Ref. 2.)