
Introduction

Polymers form one of the most important groups of materials used in modern industry. The materials in this group encapsulate great diversity in terms of their characteristics, resulting in various polymeric forms such as plastics, rubbers, fibres or dyes. Polymers are applied in almost all sectors of daily life, from households to medicine, agriculture, the automotive industry, up to microelectronics and space research. Polymers are typically composed of very large molecules, known as *macromolecules*, which usually consist of thousands of repeating units, termed *monomers*. There is huge variety in terms of the types, numbers, arrangements and combinations of monomers found in polymers, which therefore leads to an extremely wide variety of different polymeric materials. As well as synthetic polymeric materials, there are also natural and biological polymers, including proteins, silk, and cellulose.

The wide range of polymeric materials that have good processability, environmental stability, lightweight characteristics and easy machinability make polymers very useful materials. This usefulness is reflected in the worldwide production of all types of polymers, thermoplastics, resins, and rubbers, which has increased enormously since 1950, with annual average growth rates of about 15% [1]. This growth continues even now, with growth rates currently about 5–10% per annum, and polymer production reached around 230 million t in 2005 globally. The production of steel (by volume) was surpassed by polymer production in the year 1989 by about 100 million m³ [2], in such a way that today polymers are produced in greater amounts than any other group of materials. Steady growth in polymer production is also expected in the near future, based on the abovementioned characteristics and several other developments: better functionality of polymeric parts or a wider range of uses, the same or better performance achieved with lower amounts of raw material (oil) and energy, and better recycling of these materials, thus enhancing sustainable development. It is remarkable that more than 80% of all polymers are currently based on so-called mass polymers or commodities, e.g. polyethylenes, polypropylenes, polystyrene, polyvinylchloride and rubber. This renaissance of mass polymers is due to improved polymerisation, controlled molecular weight and macromolecular design, better macromolecular regularity, many modifications of the arrangements of known monomers and polymers, and modification with fillers. Examples include the broad fields of polymer blends, high-impact polymers, block copolymers or composites. A shift of interest to smaller and smaller details, from the former μm level to the now increasingly interesting nm level, is currently occurring. This increasing tendency to make structural modifications has also pushed polymer re-

search to improve morphological control through the use of electron microscopy. There is increasing interest in achieving accurate correlations between synthesis, molecular structure, morphology and properties; see Fig. I.1. The most important properties of many applications of polymers include their mechanical properties. Here, the micromechanical processes of deformation and fracture provide the bridge between structure/morphology and mechanical properties. To gain a better knowledge of structure–property correlations, much effort must be expended in studying structures, morphology and micromechanical properties. When used for polymer characterisation, electron microscopic techniques have a tremendous advantage over other methods, as they can provide a direct “view” with a high local resolution of the material of study. Other techniques do not provide direct pictures comparable to those yielded by electron microscopy, but average information about larger volumes instead. With the shift in interest to smaller and smaller structural details, electron microscopy and atomic force microscopy are becoming more and more important. The recent increased availability of high-resolution electron microscopy and atomic force microscopy is now making it possible to view molecular arrangements, and this should lead to further advancements in our understanding of the forms and structures of all types of polymer systems.

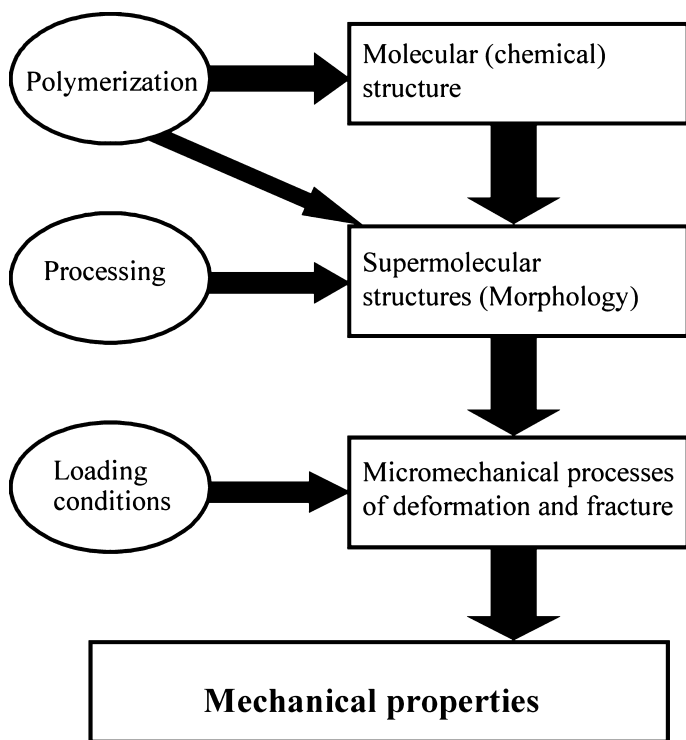


Fig. I.1. Correlations between structure, morphology, influencing parameters and mechanical properties of polymers

An additional trend in microscopy is to reveal not only structural details with improved resolution but also changes in morphology under the action of influencing parameters, such as physical and thermal ageing, outdoor weathering and mechanical loading. In particular, the influence of mechanical loading on changes in the structure and morphology of polymers – in other words, their micro- or nanomechanical properties and mechanisms – can be revealed by electron and atomic force microscopy with an otherwise unattainable accuracy. A better understanding of structure–property correlations enables the defined modification of polymeric structure or morphology and thus the improvement of polymers. While a huge variety of macromolecular and supramolecular structures exist, not all of them are of equal relevance for property improvements. Usually, only a few of the structures dictate the mechanical behaviour of the polymer; these are called “property-determining structures” [3]. A detailed knowledge of these structures and the underlying micromechanical mechanisms associated with them enable criteria to be defined for the modification and production of polymers with specifically improved or new properties [4]. This is known as the “microstructural construction of polymers” [5]. In summary, the technique of electron microscopy plays a decisive role in aiding our understanding of the structure–property correlations encountered in polymer research as well as in the polymer industry.

References

1. Menges G (1990) *Werkstoffkunde Kunststoffe*. Carl Hanser Verlag, München
2. Editor (2005) *Kunststoffe* 95:35
3. Michler GH (1992) *Kunststoff-Mikromechanik: Morphologie, Deformations- und Bruchmechanismen*. Carl Hanser Verlag, München
4. Michler GH, Baltá-Calleja FJ (eds) (2005) *Mechanical properties of polymers based on nanostructure and morphology*. CRC Press, Boca Raton, FL
5. Michler GH (1998) *Polym Adv Technol* 9:812



<http://www.springer.com/978-3-540-36350-7>

Electron Microscopy of Polymers

Michler, G.H.

2008, XX, 473 p., Hardcover

ISBN: 978-3-540-36350-7