HANSER

Preface

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Nano- and Micromechanics of Polymers

Structure Modification and Improvement of Properties

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Preface

Mechanical properties are of relevance for nearly all applications of polymers in daily life, from household to medicine, agriculture, automotive industry, up to microelectronics and space research. The improvement of properties in general and the better fitting of specific properties to defined applications is a continuous goal of polymer research. The outstanding role of the mechanical properties applies, as well, to many of the applications of polymers in which other properties are those playing the primary role, such as in medicine, optics, electronics, micro-system techniques and others. The improvement of the mechanical properties demands a better understanding of the multiple dependences between molecular structure, morphology and processing methods and ultimate mechanical properties, i. e., structure-property correlations. The bridge between structure, morphology and the mechanical properties are the micromechanical processes or mechanisms occurring at loading at microscopic and nanoscopic level: the so-called field of micro- and nanomechanics. The knowledge of these mechanisms is a key for successful development of new and the improvement of already used polymers with better properties.

In the last two decades the amount of interest of polymeric systems has gradually shifted from the μm-scale to the nm-scale region. As a consequence of the trend to produce more nanostructured polymers and to the miniaturization of components (microsystems), a better understanding of the basic mechanisms contributing to the properties of this class is needed. In addition, the knowledge of the relations between the hierarchical structure of polymers and the properties is a necessary precondition for exploiting full potential of the polymeric materials.

The detailed investigation of the very complex hierarchical structures requires the use of highly specialized techniques. Electron microscopy and atomic force microscopy, both, have developed into powerful tools in the field of polymer science. By using different techniques, morphological details at length scales from the visible (0.1 mm) up to a few 0.1 nm can be detected. Additionally, the influence of several parameters can be investigated together with the morphology of the material. In particular, under mechanical loading, the influence of the local morphology on mechanical effects that occur at nano- and microscopic level can be examined. Therefore, electron microscopy and atomic force microscopy directly contribute to a better understanding of structure–property correlations in polymers.

The interest on the topic for this book started after the first publication in this field by G. H. Michler "Kunststoff-Mikromechanik: Morphologie, Deformations- und Bruchmechanismen", Hanser 1992, as a result of the 1998 Europhysics Conference on Macromolecular Physics "Morphology and Micromechanics of Polymers" that was held in Merseburg, Germany (special volume of the Journal of Macromolecular Science-Physics, Vol. B38, 1999) and with several main lecturers of the Conference as authors of the book "Mechanical Properties of Polymers Based on Nanostructure and Morphology" (Eds. G. H. Michler, F. J. Baltá-Calleja), Taylor & Francis, 2005.

After an introductory chapter in Part I of the volume highlighting the increasing role of polymers in the world production of materials, the trends in polymer research and industry with an overview on molecular and supermolecular structures (morphology) and the mostly used polymer modifications, chapter 2 offers a summary about the main techniques and methods to investigate the nanostructure and morphology as well as the nano- and micromechanical processes and mechanisms. Here, the wide variety of preparation methods used to study polymers with the different microscopic techniques of electron microscopy and atomic force microscopy is presented and illustrated with representative micrographs. Also Small-angle X-ray scattering (SAXS) and Ultra-small angle X-ray scattering (USAXS) are discussed as well as a variety of methods of mechanical microtesting.

Part II deals with the different basic types of deformation phenomena and mechanisms during mechanical loading (chapter 3), discusses in detail the crazing behaviour from craze initiation up to craze growth and fracture (chapter 4) and describes the processes of crack propagation and final fracture phenomena together with stress concentrations at soft and hard particles and general toughness enhancing mechanisms.

In Part III the different groups of solid polymers, including amorphous and crystalline polymers, blends and rubber-toughened polymers, composites, block copolymers, nanostructured polymers, nanofibres, special polymer forms, biomedical polymers and biopolymers are presented. The characteristic features and also the variety of structures and morphology and, as consequence, the diversity of mechanical mechanisms and properties are illustrated with typical micrographs. Next to the typical morphologies and nano- or micromechanical properties, the most commonly occurring defects and failures are highlighted as well.

The book reviews research of academia and industry on key parameters that affect polymer mechanical properties with a comprehensive overview on knowledge in the field of morphology, nano-/micromechanical and failure mechanisms. It is not a summary of individual chapters of different authors, but a well-balanced description of the effects and mechanisms in general and the application to different polymers in order to improve their properties. It is an understandable description and illustration of the relevant correlations on the basic of experimental results and direct microscopic investigations. Mathematical models and theoretical analysis are used only when necessary to explain the mechanisms. The aim of the book is to give guidelines for polymer researchers, chemists, and chemical engineers or material scientists in

institutions and industry to understand principles of mechanical properties and for improving mechanical properties. Finally, the book will be also helpful for students of polymer physics, chemistry and engineering, as well as for those researchers interested in the micro- and nanoscopic world of polymers.

The book presents lots of illustrating micrographs as result of all the direct imaging methods of optical, electron and atomic force microscopy. It contains knowledge and experiences over more than three decades of different working groups in academia, university, applied research institutes and polymer industry. For a lot of microscopic investigations and micrographs we thank the former and present coworkers of GHM in Halle, Schkopau and Merseburg, in particular DI (FH) Irene Naumann, DI (FH) Helga Steinbach, Dr. Katerina Morawietz, Ingeburg Schülke, DI (FH) Sylvia Goerlitz, Cornelia Becker, Dipl.-Phys. Werner Lebek, Dipl.-Phys. Volker Seydewitz, DI Stefanie Scholtyssek, Dr. Reinhold Godehardt, Prof. Dr. Gyeong-Man Kim, Prof. Dr. Roland Weidisch and many diploma and PhD students. Valuable contributions came from Dr. Sven Henning, Halle (to chapter 7 “Semicrystalline polymers” and section 12.3. “Biomedical polymers”), Dr. Rameshwar Adhikari, Kathmandu, Nepal (to Sections 11.2 “Block copolymers” and 11.3 “Coextruded multilayered polymers”), and Dr. Ashraf Sh. Asran (to section 11.4. and 12.3.3 “Nanofibres”). In particular we have to thank DI Wolfgang Schurz for transforming many of the micrographs into a digital form, for image processing and for technical editing of figures.

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