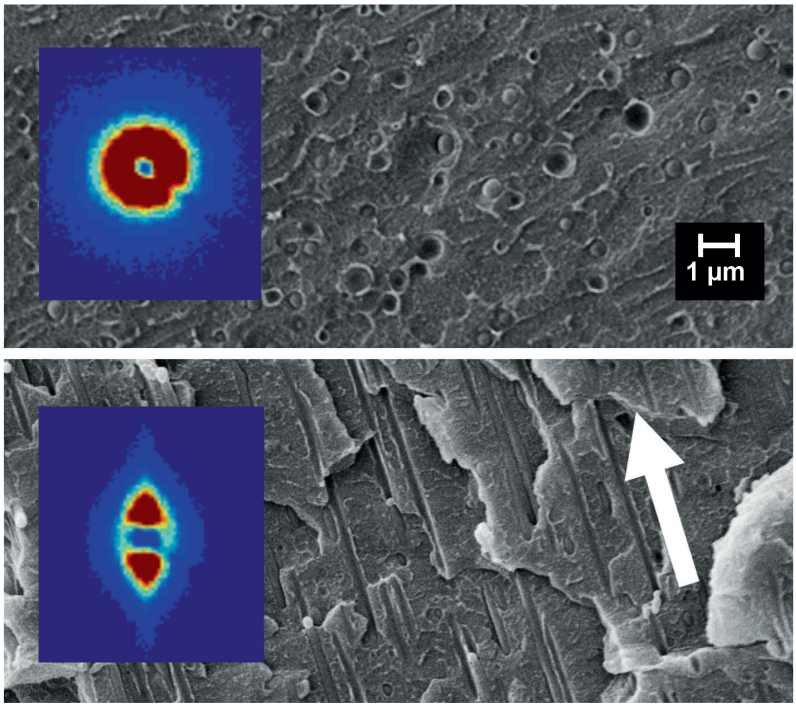
Helmut Münstedt

Rheological and Morphological Properties of Dispersed Polymeric Materials

Filled Polymers and Polymer Blends



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Preface

The idea of this book, "Rheological and Morphological Properties of Dispersed Polymeric Materials," came up during my work, together with F.R. Schwarzl, on our book, "Deformation and Flow of Polymeric Materials," published in 2014. Writing the manuscript, we found that we had to restrict ourselves to homogeneous polymer melts in order to keep the volume at a reasonable size. It is obvious, however, that flow properties of heterogeneous polymeric systems are of interest from two points of view. First, materials of that kind play an important role in practice as filled polymers and polymer blends. Their rheological behavior is the basis for an assessment of processing. In addition to the molecular structure as in the case of homogeneous melts, the heterogeneous components may build up morphological features that affect various properties. Second, it is challenging from a more fundamental aspect to find out what can be learned from rheological properties with respect to interactions between fillers and matrix molecules and those between the heterogeneous phases themselves.

Another interesting topic is the different nature of the heterogeneous phases used: rigid particles in filled polymeric materials and deformable organic phases in polymer blends. In particular, the latter ones offer a wide scope for variation and, consequently, lead to a variety of physical effects. However, an understanding of properties of heterogeneous materials is not possible without a comprehensive knowledge of the morphological development. This is different, of course, for polymers filled with particles and polymer blends. Especially interesting from a fundamental point of view and, therefore, particularly suited to educate students in the field of rheology are comparisons of the different properties of heterogeneous phases with respect to their influences on the rheological behavior. On the other hand, morphologies can be generated or changed under the influence of flow fields in the molten state. The interplay between morphology and rheology is an interesting field of research with respect to fundamental insights and applications.

Investigations of this kind on polymeric materials have been scarce in the literature and that was the reason why, over the years, research has been performed at the Institute of Polymer Materials of the Friedrich-Alexander-University Erlangen-

Nuremberg. The results of diploma and doctoral theses gradually became actual parts of the lectures for students in advanced phases of their studies. This book contains some teaching topics and, therefore, may be particularly suited for students interested in the interaction of rheological and morphological features of heterogeneous systems. Moreover, the book is thought to offer an introduction to dispersed polymers and provide valuable information for those working in research, development, and application of these materials.

By using measurements on well-defined samples it is shown how the introduction of a second phase to a polymer matrix changes rheological properties. As far as possible, the underlying mechanisms are explained, leading the reader to a broader understanding and a knowledge-based assessment of the influence of a dispersed phase on the rheological behavior. In the case of polymer blends, the interplay between morphology changes and flow patterns is a key point that is elucidated.

Several doctoral works and publications that resulted from them became the basis of this book. The investigations on polyisobutylene with various glass beads and on polymethylmethacrylate with nanoparticles were so comprehensive that my former doctoral students Michael Schmidt and Christian Triebel are coauthors of the corresponding Chapters 4 and 5. Markus Heindl as doctoral student and Zdenek Stary as senior researcher at the Institute performed many investigations on the morphology development within polymer blends under elongation. That is the reason why they are coauthors of the corresponding Chapter 17. Moreover, Zdenek Stary was the initiator of the work on compatibilized blends and most of the investigations were performed under his guidance. Therefore, he coauthors the presentations in this field described in Chapter 18.

Some readers may criticize the relatively small numbers of references on each topic. But since the book is based on many in-house results, it seemed to be an appropriate way to cite the original works that contain, of course, further literature relating to the special field. The easy access to various data bases and electronic bibliographies today allows the reader of the book to go more into details according to his or her needs and interests.

However, some experimental information, which is very special and not easily available from general sources, is given in one appendix to the particle-filled polymeric materials (Chapter 10) and in another to polymer blends (Chapter 19). The appendices are intended to guide those readers who are interested in details of the experiments. Furthermore, some results of the investigations are described in the appendices that lie somewhat outside the main topics of the book, but present interesting data with some potential for applications.

Special acknowledgement goes to the former doctoral students of mine whose results from the theses they performed under my supervision have been used in this book: Dr. Marcus Heindl, Dr. Jens Hepperle, Dr. Nikolaos Katsikis, Dr. Ute M. Kessner,

Dr. Andreas Kirchberger, Dr. Michael Schmidt, and Dr. Christian Triebel. I am grateful for their permission to use results from their works beyond the publications in scientific journals.

Additionally, the coauthors of some chapters, Dr. Marcus Heindl, Dr. Michael Schmidt, Dr. Zdenek Stary, and Dr. Christian Triebel, are thanked for many fruitful discussions and their proof reading.

The comments of Privatdozent Dr. Ulrich A. Handge on the rheological properties of particle-filled polymeric materials and immiscible and compatibilized blends, particularly from the doctoral thesis of Dr. Christian Sailer working under his guidance, are gratefully acknowledged. Discussions with Prof. Dr. Florian J. Stadler are also appreciated.

The experimental results forming the core of this book would not have been possible without the consistently high engagement of the technicians of the Institute of Polymer Materials and the motivated work of many diploma and master students. In particular, results from the diploma or master theses of Tobias Königer, Thomas Köppl, and Johannes A. Krückel are appreciated who have become PhDs in the meantime. Last but not least, M.Sc. Andrea Dörnhöfer, M.Sc. Alexander Heitbrink, and M.Sc. Ute Zeitler supported me in getting the many figures ready. All of them are thanked for their skillful assistance.

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Erlangen, June 2016 *Helmut Münstedt*

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