Preface to First Edition

This text is an outgrowth or organized compilation of the notes the authors have used to teach an introductory course on the viscoelasticity of polymers for more than 30 years for the senior author and about 15 years for the junior author. Originally, the course was taught only to graduate students, but in recent years an effort has been made to teach a modification of the course to senior-level mechanical engineering students. The authors have long held the view that the lack of knowledge of the fundamental aspects of the time and temperature behavior of polymer materials is a serious shortcoming in undergraduate as well as graduate engineering education. This is especially important in our present society because the use of polymeric materials pervades our experience both in our daily lives and in our engineering profession. Still, the basic thrust of undergraduate education and even graduate education to some degree in the areas of mechanical and civil engineering is toward traditional materials of metal, concrete, etc. Until about 25 years ago, elementary undergraduate textbooks on materials contained little coverage of polymers. Today, many elementary materials texts have several chapters on polymers, but in general, the thrust of such courses is toward metals. Even the polymer coverage that is now included treats stress analysis of polymers using the same procedures as for metals and other materials and therefore often misleads the young engineer on the proper design of engineering plastics. Thus, it is not surprising that some structural products made from polymers are often poorly designed and do not have the durability and reliability of structures designed with metallic materials.

For the above reasons, the view of the authors is that specific courses on polymer materials as well as associated stress analysis and engineering design need to be offered to every engineer. The present text has been developed with this in mind. The intent is to have sufficient coverage for a two-semester introductory sequence that would be available to upper-class undergraduates and first-year graduate students. The level is such that only basic knowledge of solid mechanics and materials science are needed as prerequisites. The book is intended to be self-sufficient even for those that have little formal training in solid mechanics, and therefore, chemical engineers; materials, forestry, chemistry, and bioengineering students; as well as mechanical and civil engineering students can use this text successfully. Similarly, because chemistry background is often weak for nonchemical engineers, introductory material is provided on the chemical basis of polymers, which is essential for proper appreciation of the thermomechanical response.

Another major objective is for the text to be readable by recent engineering graduates who have not had the advantage of a formal course on polymer science or viscoelasticity. The reason, of course, is that today's engineering curricula, both undergraduate and graduate, have few extra hours such that new courses can be accommodated in degree plans. Therefore, a book such as this one should be of great value to the young engineer who finds him/herself in a position heavily involved with the engineering design and use of polymer-based materials. In addition, a text such as this should be invaluable to those cross-disciplinary scientists such as biologists, bio-chemists, etc. that need to understand the basic background to rigorous mechanics approaches to the design of structures made with polymer-based materials.

The first chapter gives insight to the historical aspects of the subject. A review of basic mechanics of materials (strength of materials) and materials science is given in Chap. 2. Chapter 3 gives an introduction to the mechanical properties of polymers and how they are determined as well as general information on optical, electrical, and other properties. Chapter 4 is an introduction to the general character of polymers from a molecular viewpoint and is valuable in assessing the mechanisms associated with viscoelastic deformations. Chapter 5 and beyond speak to the formal mathematics and experimental methods associated with the relationship between stress and strain in viscoelastic solids, both linear and nonlinear, as well as stress analysis and failure.

Acknowledgments

Perhaps the first to receive our grateful acknowledgment are all the authors of books and articles that we have referenced as well as those authors from whom we have gained information that we have internalized so well that the original source of inspiration is forgotten and therefore we cannot properly acknowledge. We know that this text would not have been possible without the guidance from professors and fellow students over our formative years while students at our respective universities; N.C. State, Northwestern and Stanford (HFB), and Virginia Tech and Caltech (LCB). In addition, we surely have greatly benefited from the council, encouragement, and friendship of fellow faculty at the universities where we have had the pleasure to be faculty members; N.C. State, Virginia Tech, UTSA, and University of Houston (HFB) and Northwestern (LCB). Certainly, we have had the privilege to guide and be guided by our graduate students and postdocs over the years that deserve enormous credit for their hard work and the many papers and reports that we have jointly published. As any professor must admit, our success would be small if not for the dedication, energy, and resourcefulness of our students – both graduate and

undergraduate. Both authors would also like to thank colleagues and staff at University of Poitier in France, the Free University of Brussels in Belgium (HFB), and the Helmut-Schmidt-Universität in Hamburg, Germany (LCB), respectively, where each of us has spent many pleasant hours with colleagues discussing the subject of this book plus many other issues. We especially wish to thank Ms Susanne Pokossi for her skillful, cheerful, and tireless assistance in the preparation of the final version of this book.

Foremost of all, we gratefully acknowledge those closest to us – our families, our life partners, and, of course, our children. We owe them much for their patience, guidance, camaraderie, and, most of all, their love.

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Preface to Second Edition

In the time since our first edition was released, the use of polymers and their composites in structures, devices, medicine, and all varieties of commercial products has continued to increase. We have witnessed the launch of what the news media dubbed the "plastic plane," Boeing's 787 Dreamliner, with over 50 % polymer composites comprising its structure. There has been an explosion of 3D printing technology using polymers as means of prototyping, designing, and creating complex components and providing options for easy customization. This continuously increasing use of polymers for their weight savings, durability, and manufacturability make the content of this monograph even more important as a resource for all engineers. In spite of the increased use of polymers, the ever-increasing base of knowledge combined with the constant 4-year timeline of university study prevents significant inclusion of polymer engineering concepts in a typical undergraduate engineering education. As with the first edition, we believe this book addresses a key niche by providing a one-stop resource for understanding both the underlying materials science of polymers as well as the mathematical description of their thermomechanical behavior. Armed with this text, engineers are enabled to better understand and design polymeric structural components and devices.

In this second edition, new content has been introduced in nearly all chapters, and numerous changes have been made to clarify the text. Marketing data has been updated in Chap. 3, and the discussion of strain measurement techniques has been updated to include more modern approaches to strain measurement using digital imaging techniques such as the digital imaging correlation method (DIC). Also included is a brief discussion of strain measurement at the micro- or nanoscale with reference citations for further study. More detail has been added in Chap. 4 about block copolymers and thermoplastic elastomers. Also, a section on microscopy has been added at the end of the chapter where the capabilities of near-field scanning optical microscopy (NSOM) and electron microscopy in the realm of polymers are discussed. More detail about the origin of the time–temperature superposition principle (TTSP) is given in Chap. 7, and a new Appendix C has been added on the durability and accelerated life prediction of structural polymers. Appendix D has been added that gives additional interesting detail about Herbert Leaderman and his connection to the invention of the electrical resistance strain gage.

Acknowledgments

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Again, most of all, we gratefully acknowledge those closest to us – our families, our life partners, and, of course, our children. We owe them much for their patience, guidance, camaraderie, and most of all, their love.

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