RUBBERLIKE ELASTICITY

Elastomers and rubberlike materials form critical components in diverse applications that range from tires to biomimetic devices and are used in chemical, biomedical, mechanical and electrical engineering. This updated and expanded edition provides an elementary introduction to the physical and molecular concepts governing the behavior of elastomeric materials. The coverage of fundamental principles has been greatly extended and fully revised, with analogies to more familiar systems such as gases, producing an engaging approach to this phenomenon. Dedicated chapters on novel uses of elastomers, covering bioelastomers, filled elastomers and liquid-crystalline elastomers are included, illustrating established and emerging applications at the forefront of physical science. With problem sets and corresponding solutions, and a list of experiments and demonstrations, this is a self-contained introduction to the topic for graduate students, researchers and industrialists working in the applied fields of physics and chemistry, and polymer science and engineering.

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RUBBERLIKE ELASTICITY

A Molecular Primer

Second Edition

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Contents

Preface to the first edition

This book was prepared to provide a concise, elementary presentation of the most important aspects of rubberlike elasticity. Along with many of our colleagues, we have long felt a need for such an introductory treatment. The present time seems propitious because of new insights into the subject provided by theory and numerous recent developments on the experimental side. We have treated the subject from the point of view of the physical chemist or chemical physicist. Accordingly, there is a very pronounced emphasis on molecular concepts and physical ideas, particularly those underlying some of the more abstract theory. The coverage is restricted to equilibrium properties, with no significant consideration of the huge body of literature on polymer viscoelasticity. The approach is quite tutorial, and the only background required of the reader is familiarity with the basic concepts of physical chemistry. Consequcntly, readers already knowledgeable about some aspects of rubberlike elasticity will be inclined to move through a few of the sections relatively rapidly. Nonetheless, we hope that all readers will benefit from the general overview and will also find some specific topics to be of particular interest and useful in their own research programs. The material presented should be sufficient for a one-term introductory course on the subject.

To a large extent, the book can be divided into two major parts. Part A deals primarily with fundamentals; Part B considers additional topics, many of which are still under intensive investigation and thus necessarily discussed in only a preliminary manner. From a positive point of view, the tentative nature of these capsule summaries should stimulate further work in these areas. For both Parts A and B, some of the more detailed material has been placed in appendixes.

Both of us had the great privilege of collaborating extensively with the late Paul J. Flory, who contributed so remarkably to an understanding of rubberlike elasticity, among other topics in the area of polymer science. Our approach to this subject is largely his, and it would be impossible (and undesirable) to remove these partialities

completely. Although they are there, every effort has been made to provide some balance by commenting on other approaches and schools of thought.

It is a great pleasure to acknowledge the invaluable assistance provided by Mrs. Jane Hershner, who typed all the drafts of the manuscript. She either has the patience of a saint or is a superb actress (probably the latter).

Finally, we wish to dedicate this book to the memory of Paul Flory, because of his seminal contributions to the area of rubberlike elasticity, but more generally on behalf of the countless people he inspired, both as a scientist and an extraordinary, profound human being.

James E. Mark
Cincinnati, Ohio

Burak Erman
Istanbul, Turkey
June 1998

Preface to the second edition

In this edition, we made several changes in both content and organization. In order to reduce cross-referencing, we combined the chapters on elastic equations of state and force as a function of deformation into a single chapter, Chapter 7, under the heading "Elastic equations of state and force–deformation relations". We updated Chapter 10, "Force as a function of structure", under the new heading, "Model elastomers". Since volume phase transitions are now gaining fundamental importance, we moved Chapter 17, "Osmotic compressibility, critical phenomena, and gel collapse" to Part I, under the new name: Chapter 8, "Swelling of networks and volume phase transitions". We joined Chapters 14 and 15 on "Birefringence" and "Segmental orientation" into a single new chapter, Chapter 14, "Birefringence and segmental orientation", because both of these chapters are closely related and this merge reduces redundancy in the treatment of the subject. We significantly condensed and moved Chapter 16, "Rotational isomerization", to the end of the new Chapter 12, "Strain-induced crystallization and ultimate properties". This change was made due to lack of computational work and interest in the field of rotational isomerization in stretched elastomers since the first edition. We feel, however, that the importance of computational work on highly stretched chains should not be underestimated. The new chapter, Chapter 3, "The single molecule: theory and experiment", shows new possibilities in this area. We added a new chapter, Chapter 16, "Liquid-crystalline elastomers", due to the importance gained by this subject in recent years. The book is now reduced to 19 chapters from the original 21 chapters.