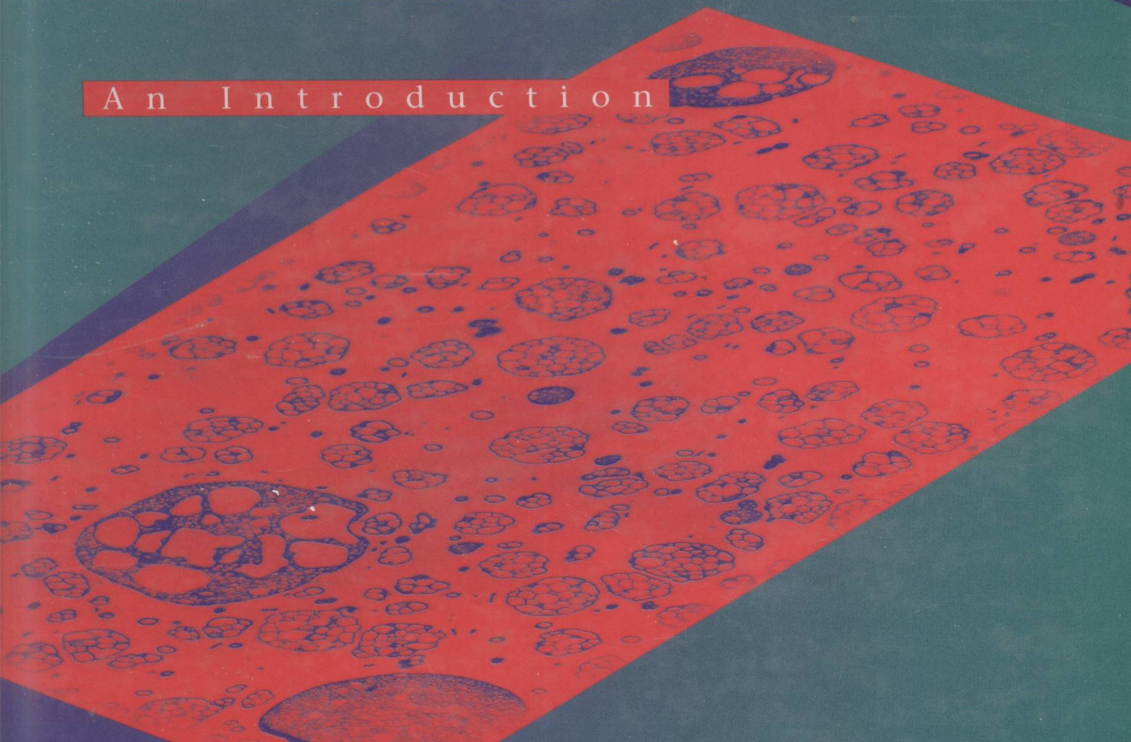
POLYMERIC MULTICOMPONENT MATERIALS

An Introduction



L. H. SPERLING

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An Introduction

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This book is dedicated to the memory of my teachers,

Dr. William R. Krigbaum

of Duke University, who was the most patient man I ever knew, and

Dr. Arthur V. Tobolsky

of Princeton University, who taught me how to organize a modern laboratory.

While the day-to-day setting in both laboratories was polymer science, both men had the overriding mission of teaching us the *Art of Research*. Their professional children, grandchildren, and even great-grandchildren now populate the ranks of scientists and engineers around the globe.

PREFACE

Polymer blends and composites were born of sheer necessity: Although early polymers were light and inexpensive and promised to fill new application roles, the materials were weak or brittle and often unsatisfactory in performance. In about 1905, carbon black was discovered to toughen tire rubber. The earliest tires lasted about 5000 miles at speeds of 25 miles per hour. Now, they last 50,000 miles at 55 miles per hour. This has been due in significant measure to more finely dispersed carbon blacks, stronger tire cords, and improved adhesion of these materials to the rubber.

In 1914, rubber (then natural rubber, of course) was first added to phenol-formaldehyde phonograph records and other materials, providing a measure of toughness. In the mid 1940s, polybutadiene rubber was added to styrenic compositions, leading to high-impact polystyrene and ABS materials. From there, the list of commercial polymeric materials containing another phase grew rapidly.

Nearly all of this early work was empirical. People tried many things. If something worked better, they used it. There were few basic relationships, and fewer guiding principles.

In 1976, Plenum Press published *Polymer Blends and Composites*, by John Manson and the present author, in which we attempted to present the entire field as a unit for the first time. We organized what theory there was and sampled the best of the experimental data then available. Later, we considered a second edition of this book. Alas, John took sick and passed away. When I next taught out of the text, I realized it had now become hopelessly outdated. If the subject were to be covered again, it must be done from the beginning, fresh.

Here, I must confess one of the secrets of why I write books: It is a form of self-education. I laid out a map of current readings for me to do, conferences to participate in, people to speak with, and so on. This, indeed, was 80–90% of the work of preparing the book. The remaining 10–20% of the time was setting it down on paper so I, myself, could find this information later. The inverse was also true: I never would have systematically read all of this literature if I wasn't going to write a book about it.

Of course, there is another important reason why I wrote this book: No modern text covering the basics of the field seemed to exist. There was nothing to teach from except notes. It was obvious that professionals also lacked a modern book for an introduction to the field. Thus, this book is dedicated to the many workers in the field who have either provided information used in the book or who will want to read this book the better to advance themselves professionally. Who wants to write a book that isn't needed?

While *Polymer Blends and Composites* organized the field of that day, there have been many major areas of advance. Two of the most important subfields created were the thermodynamics of polymer blend miscibility, the introduction of phase diagrams, and so on, and the kinetics of phase separation in terms of spinodal decomposition versus nucleation and growth.

A third new subfield, now growing explosively, relates to polymer surfaces and interfaces. This area was born around 1989 with a series of articles appearing in *Macromolecules* and other journals. Suddenly, instruments and experiments were available to investigate the structure of interfaces, and the theorists were there to provide novel and exciting explanations of the results. When this book was started 3 years ago, I planned on having one chapter called "Polymer Surfaces and Interfaces." Now, the reader will find that there are four chapters in the center of this book, under the broader title, "Part II: Polymer Surfaces and Interfaces." The conformation of polymer chains at surfaces and interfaces is becoming clear, as are the important engineering areas of strengthening the interfaces mechanically via both chain entanglements and bonding schemes.

Now, the broader field demands a new title: *Polymeric Multicomponent Materials*. Since this book is intended as an introduction to this field, I trust that the title usage will be obvious. The book has 11 chapters, laid out in three parts. Part I is called "Fundamental Relationships," presenting a number of concepts, theories, nomenclature, and basic experimental facts common to both two-polymer and polymer–nonpolymer combinations. The effects of component mixing on the glass transitions, phase continuity and inversion, thermodynamics of mixing, and modeling of the modulus and other mechanical quantities are treated here. The mechanisms of fracture and fracture resistance are introduced, along with the concepts of how two-phased systems can impart toughness. Part II has already been discussed above. Part III, "Selected Engineering Polymer Materials," provides more advanced and/or engineering concepts and understanding of a series of materials including rubber-toughened plastics, block copolymers, and interpenetrating polymer networks. The book concludes with a brief chapter titled, "Overview and Future." Overall, the coverage is about 80% relating to the fields of polymer blends, blocks, grafts, and IPNs, and about 20% relating to polymer composites, including carbon-black-reinforced rubber, glass fiber-reinforced systems, and the incorporation of particulates.

As always, there are many people to be thanked. First of all, the Lehigh University Fairchild–Martindale Library provided a carrel with a desk, a lock on the door, and no phone. This carrel is placed magnificently in the middle of the scientific and engineering stacks. Drafts of this book were read by my students, who repeatedly pointed out ways to improve the manuscript. Ms. Andrea Pressler provided many of the outstanding photographs in the book. Lastly, my secretaries, Ms. Virginia Newhard and Ms. Kathy Kennery, provided invaluable typing and administrative assistance.

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