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Reactive Polymer Blending

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Foreword

Since World War II, the industry based on polymeric materials has developed rapidly and spread widely. The polymerization of new polymeric species advanced rapidly during the sixties and the seventies, providing a wide range of properties. A plethora of specialty polymers have followed as well, many with particularly unique characteristics. This evolution has been invigorated by the implementation of metallocene catalyst technology. The end-use of these materials has depended on the development of new techniques and methods for forming, depositing, or locating these materials in advantageous ways, which are usually quite different from those used by the metal or glass fabricating industries. The importance of this activity, ''Polymer Processing'', is frequently underestimated when reflecting on the growth and success of the industry.

Polymer processes such as extrusion, injection molding, thermoforming, and casting provide parts and products with specific shapes and sizes. Furthermore, they must control, beneficially, many of the unusual and complex properties of these unique materials. Because of their high molecular weights and, in many cases, tendency to crystallize, polymer processes are called upon to control the nature and extent of orientation and crystallization, which in turn have a substantial influence on the final performance of the products made. In some cases, these processes involve synthesizing polymers within a classical polymer processing operation, such as reactive extrusion. Pultrusion and reaction injection molding both synthesize the polymer and form a finished product or part all in one step, evidence of the maturing of the industry. A new family of polymer blends is prepared by reactive polymer blending processes. For these reasons, successful polymer process researchers and engineers must have a broad knowledge of fundamental principles and engineering solutions.

Some polymer processes have flourished in large industrial units, synthetic fiber spinning for example. However, the bulk of the processes are rooted in small- and medium sized entrepreneurial enterprises in both developed and new developing countries. Their energy and ingenuity have sustained growth to this point, but clearly the future will belong to those who progressively adapt new scientific knowledge and engineering principles, which can be applied to the industry. Mathematical modeling, online process control and product monitoring, and characterization based on the latest scientific techniques will be important tools in keeping these organizations competitive in the future.

The Polymer Processing Society was founded in Akron, Ohio, in 1985 with the aim of providing a focus, on an international scale, for the development, discussion, and dissemination of new and improved polymer processing technology. The Society facilitates this by sponsoring several conferences annually and by publishing the journal International Polymer Processing, and the volume series Progress in Polymer Processing. This series of texts is dedicated to the goal of bringing together the expertise of accomplished academic and industrial professionals. The volumes have a multi-authored format, which provides a broad picture of the volume topic viewed from the perspective of contributors from around the world. To accomplish these goals, we need the thoughtful

insight and effort of our authors and volume editors, the critical overview of our Editorial Board, and the efficient production of our Publisher.

This volume deals with the reactive polymer blending in the development of new polymer materials, which attain the specific mechanical properties due to unique combination of their component polymers. These processes have developed into what is arguably the best route to prepare new materials by combining different, existing polymers while most monomers cannot be easily copolymerized to gain intermediate properties. Many excellent polymer blends have been developed economically for the major applications in the transportation, electronic, appliances and packaging area with properties important in each application. Therefore, most important in this volume are the extensive discussions on the unique aspects of reactive blending in the developments of polymer blends, and morphology changes and how these lead to improvements in properties especially mechanical properties. Therefore this volume covers all aspects, from fundamentals of interfacial reactions and morphology developments, compatibilizer chemistry and design, reactive blending process fundamentals, to the process equipment and present major classes of commercially significant blends. This volume includes numerous contributions, industrial and academic, from Europe as well as Asia and North America and, as such, forms a very useful contribution to the plastics industries. This volume was initiated by Dr. Warren Baker, my predecessor and one of the volume editors, and became the third volume in this series with which I had the pleasure to be associated.

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Kun Sup Hyun
Series Editor

Preface

This volume was written to support an area of very significant technical and industrial interest in the field of polymer development. Over the last 30 years polymer blends of many types have become the dominant material class of polymers in commercial practice. From infant beginnings in the 1970s, the use of carefully designed chemistry has grown to augment physical blending strategies and several good volumes have been written which cover ''Polymer Blends'' in general. However, none have focussed specifically on reactive blending and the material and process issues involved. This is an attempt to do just that.

Polymer blends have grown to take on a very significant role in the major application areas for polymers. A plethora of applications in the packaging, electronics/electrical, transportation, and construction industries have been instrumental in allowing polymeric materials to expand against other, more traditional materials. Many of these blends are phase separated, which leads to the need to control morphology and hence properties. Cleverly designed di-block and tri-block copolymers, which had no chemical functionality, were developed which aided in improving the performance of blends. However, their complexity of design and difficulty of use led to the innovations starting in the 1970s to use selective chemistry to enhance performance by controlling and stabilizing preferred morphologies and influencing interfacial adhesion. Some of the first applications and developments related to polyamide blends, but now reactive blending and compatibilization extends to essentially all polymeric material classes.

This volume covers a wide range of the issues important in reactive blending. It starts in Chapter 1 with an overview of some of the basic fundamental issues in polymer blending in general and feeds into a brief overview of the historical developments in reactive blending. Chapter 2 is a comprehensive review and bibliography of the many classes of chemistry, which have been reported in reactive blending. Chapter 3 deals with the dynamics and interfacial issues, which are at play and Chapter 4 discusses the design and function of reactive compatibilizers. Chapter 5 focuses in on the topic of morphology development and the rheological factors that are so influential in reactive blending. Chapters 6 and 7 deal with the processing issues and process equipment involved. Chapter 8 takes the most extensively investigated reactive blend material, polyamide, and follows it through the many developments as an example of a particular class. Chapter 9 makes a departure and deals with a new, possibly emerging approach to blending, using low molecular weight reactive additives. While we have not covered all aspect of reactive blending, we trust that this will be a useful contribution to the field for both fundamental researchers and industrial practicioners.

In keeping with the philosophy and membership of the Polymer Processing Society this volume is the collaboration of authors from Europe, the Americas, and Asia. We believe this diversity of views and inputs is important in disseminating the latest of technical developments. Many authors have assisted in this project but we are particularly indebted to N. C. Liu, G. Groeninckx, R. Jerome, T. Sakai, and K. Akkapeddi for co-ordinating their

chapters. Several individuals provided helpful reviews of the chapters including C. Tzoganakis, C. K. Shih, J. Curry, L. Geottler and S. Balke. We hope this volume will further contribute to the field of polymer blending.

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