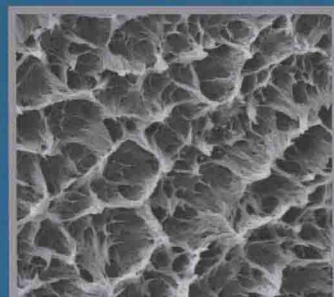


Fractography in Failure Analysis of Polymers



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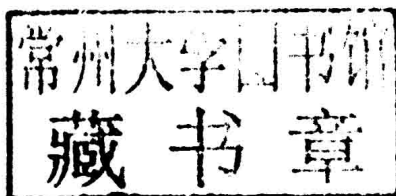
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Foreword

This book is a welcome and needed addition to the technical literature. It has the advantage of being coauthored as opposed to being a collection of symposium papers or an edited volume. This provides a book which can be better used as an educational tool. The years of experience of the authors in the field of failure analysis of polymers lends credibility to their approach for understanding and investigating the failure of polymer products. This book not only provides chapters dealing with fundamentals of failure analysis and characterization methods, but also includes a significant number of case studies based on the personal experiences of the authors. The case studies cover a very wide range of polymers, product types, and failure modes and greatly add to the value of the book.

I began studying polymer fracture, fracture toughness, and fracture surfaces as part of my doctoral thesis at MIT from 1961 to 1963. At that time, I could find only one other scientist characterizing fracture toughness of polymers and, fortunately, I had the opportunity to meet with him during my own research. In 1961, studying fracture surfaces was done with optical microscopes, and images were typically recorded on Polaroid film. Scanning electron microscopes were still a few years away, and once they became available, great advances were made in characterizing microscopic details of polymer fracture surfaces.

L. J. Broutman & Associates, which I founded in 1982, became the leading consulting company in North America conducting failure analyses on polymer and polymer composite products. Clients included municipalities, private corporations, government agencies, and law firms. For a major failure analysis involving systemic failures, we would use chemists, mechanical engineers, materials scientists, and microscopy experts working together to understand and alleviate the problem. Dale Edwards and Andy Shah were key staff members and had the opportunity to work on some of the most major polymer product failures in North America in the 1980s and 1990s. Consulting on failures in products ranging from silicone breast implants to large diameter reinforced plastic irrigation piping was common.

All three authors in their current employment continue to do failure analyses on a variety of polymeric products. It should be clear that this

book is based on years of experience determining causes of failure and is an authoritative source of information for students, engineers, and scientists interested in learning the methodologies required for effective failure analysis.

Larry Broutman

Preface

The book, “Fractography in Failure Analysis of Polymers, is the culmination of many years of practical experience in studying the behavior of polymer materials and the performance of plastic products in service. The professional careers of all three authors have involved examining, testing, and evaluating plastic products and materials to determine the root cause of product failure on a routine basis.

The subject of product failure is a sensitive and often a controversial issue. A general response to a product failure is to initiate an investigation to determine how and why the product failed. However, the results of these investigations are generally not publicized, because, by doing so, someone or some entity must take accountability for the cause of the product failure. The authors have observed that, because of the lack of literature detailing product failures, errors in the decision making processes in product design, material selection, and material processing often do not get corrected, and the same mistakes are repeated. As a result, the feedback loop between failure *analysis* and failure *prevention* is often missing.

Only a few books are available as a reference to the current generation of engineers to help in understanding how and why plastic products fail. The literature is particularly sparse when it comes to details concerning the use of fractography in plastic product failures. Typically, the subject of fractography in books is explored in the context of describing the fracture surface of samples tested under laboratory conditions. Many textbooks discuss the fracture process of polymers by evaluating the fracture surface features of samples that were failed in a controlled manner in which the temperature, strain rate, or chemical exposure was varied. Although it is useful to study the fracture characteristics of laboratory-tested specimens, the translation of this knowledge to an understanding of the fracture process in a plastic part with a complex geometry, loading, and environmental exposure history requires substantial experience. Moreover, most books discuss fractography of polymers by showing fracture surface features at relatively high magnifications that were obtained using a scanning electron microscope (SEM). What is not discussed in these books is the amount of information that can be obtained by visual observation and optical microscopy with only 10x to 50x magnification.

This book is intended to give the reader information on how to utilize fractography effectively in the course of a root cause failure analysis of a plastic product. In Chapter 6, numerous plastic product failure case studies are provided as examples to illustrate the use of fractography and other aspects of failure analysis. Our aim in providing this information is to provide real-world examples of these tools in action for the benefit of engineers and material scientists but also to assist manufacturers in preventing future plastic product failures.

Acknowledgments

The concept for this book developed from material originally included in the Fracture and Failure Analysis Seminar series presented by L. J. Broutman & Associates (LJBA) in cooperation with the Society of Plastics Engineers (SPE). In particular, the authors were inspired by conversations with and the writings and teachings of Dr. Lawrence J. Broutman, Dr. Paul K. So, Dr. Eric Baer, Dr. Anne Hiltner, and Dr. Lee Nylander. This book would not have been possible without the knowledge gained from years of working with these individuals.

It has been a privilege for the authors to work at various companies that have provided failure analysis services. This work has allowed the three of us to gain widespread experience in conducting fractographic examinations of plastic failures and to conduct in-depth failure analyses on a wide variety of materials and applications. This work has continued at our current employer, Engineering Systems Inc. (ESI). The authors would like to acknowledge our colleagues at ESI for their support of this project. In particular we would like to thank Dr. Donald Duvall, Ronald Parrington, Will Pinkston, and Dr. Pierce Umberger, who reviewed portions of the manuscript and provided valuable feedback. Many others helped with laboratory work, information gathering, and preparation of figures and photographs, all of which were important additions to the book: Dr. Michael Hanks, Jeff McDougall, Dustin Turnquist, Dr. Garth Freeman, Stan Sangdahl, Scott Karlins, and Lissa Maratea.

We would also like to thank our families for their support, as this book would not have been possible without it.

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