About the Author

Kevin P. Menard is a chemist with research interests in materials science and polymer properties. He has published over 50 papers and/or patents. Currently a Senior Product Specialist in Thermal Analysis for the Perkin-Elmer Corporation, he is also an Adjunct Professor in Materials Science at the University of North Texas. After earning his doctorate from the Wesleyan University and spending 2 years at Rensselaer Polytechnic Institute, he joined the Fina Oil and Chemical Company. After several years of work on toughened polymers, he moved to the General Dynamics Corporation, where he managed the Process Engineering Group and Process Control Laboratories. He joined Perkin-Elmer in 1992.

Dr. Menard is a Fellow of the Royal Society of Chemistry and a Fellow of the American Institute of Chemists. He is active in the Society of Plastic Engineers, where he is a member of the Polymer Analysis Division Board of Directors. He has been treasurer for the North American Thermal Analysis Society, a local officer of the American Chemical Society, and is a Certified Professional Chemist.
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Preface

As an educator, and also because of my involvement in Short Courses preceding the International Conferences on Materials Characterization (POLYCHAR), I have found repeatedly that some practitioners of polymer science and engineering tend to stay away from dynamic mechanical analysis (DMA). Possibly because of its use of complex and imaginary numbers, such people call the basic DMA definitions impractical and sometimes do not even look at the data. This is a pity, because DMA results are quite useful for the manufacturing of polymeric materials and components as well as for the development of new materials.

Year after year, listening to Kevin Menard’s lectures at the International Conference on Polymer Characterization (POLYCHAR) Short Courses on Materials Characterization, I have found that he has a talent for presentation of ostensibly complex matters in a simple way. He is not afraid of going to a toy store to buy slinkies or silly putty — and he uses these playthings to explain what DMA is about. Those lectures and the DMA course he teaches for Perkin-Elmer, which is also part of the graduate-level thermal analysis course he teaches at University of North Texas, form the basis of this text.

The following book has the same approach: explaining the information that DMA provides in a practical way. I am sure it will be useful for both beginning and advanced practitioners. I also hope it will induce some DMA users to read more difficult publications in this field, many of which are given in the references.

Witold Brostow
University of North Texas
Denton, in July 1998
**Author’s Preface**

In the last 5 to 10 years, dynamic mechanical analysis or spectroscopy has left the domain of the rheologist and has becoming a common tool in the analytical laboratory. As personal computers become more and more powerful, this technique and its data manipulations are becoming more accessible to the nonspecialist. However, information on the use of DMA is still scattered among a range of books and articles, many of which are rather formidable looking. It is still common to hear the question “what is DMA and what will it tell me?” This is often expressed as “I think I could use a DMA, but can’t justify its cost.” Novices in the field have to dig through thermal analysis, rheology, and material science texts for the basics. Then they have to find articles on the specific application. Having once been in that situation, and as I am now helping others in similar straits, I believe there is a need for an introductory book on dynamic mechanical analysis.

This book attempts to give the chemist, engineer, or material scientist a starting point to understand where and how dynamic mechanical analysis can be applied, how it works (without burying the reader in calculations), and what the advantages and limits of the technique are. There are some excellent books for someone with familiarity with the concepts of stress, strain, rheology, and mechanics, and I freely reference them throughout the text. In many ways, DMA is the most accessible and usable rheological test available to the laboratory. Often its results give clear insights into material behavior. However, DMA data is most useful when supported by other thermal data, and the use of DMA data to complement thermal analysis is often neglected. I have tried to emphasize this complementary approach to get the most information for the cost in this book, as budget constraints seem to tighten each year. DMA can be a very cost-effective tool when done properly, as it tells you quite a bit about material behavior quickly.

The approach taken in this book is the same I use in the DMA training course taught for Perkin-Elmer and as part of the University of North Texas course in Thermal Analysis. After a review of the topic, we start off with a discussion of the basic rheological concepts and the techniques used experimentally that depend on them. Because I work mainly with solids, we start with stress–strain. I could as easily start with flow and viscosity. Along the way, we will look at what experimental considerations are important, and how data quality is assured. Data handling will be discussed, along with the risks and advantages of some of the more common methods. Applications to various systems will be reviewed and both experimental concerns and references supplied.

The mathematics has been minimized, and a junior or senior undergraduate or new graduate student should have no trouble with it. I probably should apologize now to some of my mentors and the members of the Society of Rheology for what may be oversimplifications. However, my experience suggests that most users of
DMA don’t want, may not need, and are discouraged by an unnecessarily rigorous approach. For those who do, references to more advanced texts are provided. I do assume some exposure to thermal analysis and a little more to polymer science. While the important areas are reviewed, the reader is referred to a basic polymer text for details.

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Acknowledgments

I need to thank and acknowledge the help and support of a lot of people, more than could be listed here. This book would never have been started without Dr. Jose Sosa. After roasting me extensively during my job interview at Fina, Jose introduced me to physical polymer science and rheology, putting me through the equivalent of a second Ph.D. program while I worked for him. One of the best teachers and finest scientists I have met, I am honored to also consider him a friend. Dr. Letton and Dr. Darby at Texas A&M got me started in their short courses. Jim Carroll and Randy O’Neal were kind enough to allow me to pursue my interests in DMA at General Dynamics, paying for classes and looking the other way when I spent more time running samples than managing that lab. Charles Rohn gave me just tons of literature when I was starting my library. Chris Macosko’s short course and its follow-up opened the mathematical part of rheology to me.

Witold Brostow of the University of North Texas, who was kind enough to preface and review this manuscript, has been extremely tolerant of my cries for help and advice over the years. While he runs my tail off with his International Conference on Polymer Characterization each winter, his friendship and encouragement (translation: nagging) was instrumental in getting this done. Dr. Charles Earnest of Berry College has also been more than generous with his help and advice. His example and advice in how to teach has been a great help in approaching this topic.

My colleagues at the Perkin-Elmer Corporation have been wonderfully supportive. Without my management’s support, I could have never done this. John Dwan and Eric Printz were supportive and tolerant of the strains in my personality. They also let me steal shamelessly from our DMA training course I developed for PE. Dr. Jesse Hall, my friend and mentor, has supplied lots of good advice. The TEA Product Department, especially Sharon Goodkowsky, Lin Li, Greg Curran, and Ben Twombly, was extremely helpful with data, advice, samples, and support. Sharon was always ready with help and advice. My counterparts, Dave Norman and Farrell Summers, helped with examples, juicy problems, and feedback. A special thanks goes to the salesmen I worked with: Drew Davis, Peter Muller, Jim Durrett, Ray Thompson, Steve Page, Haidi Mohebbi, Tim Cuff, Dennis Schaff, and John Minnucii, who found me neat examples and interesting problems. Drew deserves a special vote of thanks for putting up with me in what he still believes is his lab. Likewise, our customers, who are too numerous to list here, were extremely generous with their samples and data. I thank Dr. John Enns for his efforts in keeping me honest over the years and his pushing the limits of the current commercially available instrumentation. John Rose of Rose Consulting has been always a source of interesting problems and wide experience. In addition, he proofread the entire manuscript for me. Nandika D’Sousa of UNT also reviewed a draft copy and made helpful suggestions. A very special thanks goes to Professor George Martin of Syracuse
University. Dr. Martin was kind enough to proofread and comment extensively on the initial draft, and many of his suggestions were used. I feel this book was greatly improved by incorporating their comments, and they have my heartfelt thanks. Many deserving people cannot be mentioned, as I promised not to tell where the samples came from.

More personally, Professor Paul R. Buitron III and Dr. Glenn Morris were constant sources of encouragement and practical advice. Paul especially was a great example, and it is largely due to him that I stayed vaguely sane during this effort. Matthew MacKay, John Essa, and Tom Morrissey also helped with their good advice and support. Felicia Shapiro, my editor, put up endlessly with my lack of a concept of deadline. Finally, thanks are offered to my wife, Connie, and my sons, Noah and Benjamin, for letting me write this on nights when I should have been being an attentive husband and father. I promise to stop spending all my time on the computer now so the boys can have their turn.
Dedication

To my wife, Connie,
Tecum vivere amen,
tecum obeam libens.
Homer, Epodes, ix

And to Dr. Jose Sosa,
My teacher, mentor, and friend.