



# **POLYMERS AND MULTICOMPONENT POLYMERIC SYSTEMS THERMAL, THERMO-MECHANICAL AND DIELECTRIC ANALYSIS**

Edited by  
Jose James, K.P. Pramoda, and Sabu Thomas



CRC Press  
Taylor & Francis Group  
6000 Broken Sound Parkway NW, Suite 300  
Boca Raton, FL 33487-2742

© 2020 by Taylor & Francis Group, LLC  
CRC Press is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed on acid-free paper

International Standard Book Number-13: 978-1-138-59814-0 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access [www.copyright.com](http://www.copyright.com) (<http://www.copyright.com/>) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

**Trademark Notice:** Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Visit the Taylor & Francis Web site at  
<http://www.taylorandfrancis.com>

and the CRC Press Web site at  
<http://www.crcpress.com>

# Contents

Preface.....	vii
Editors.....	ix
Contributors .....	xi
<b>Chapter 1</b> Thermal, Thermo-mechanical, and Dielectric Characterization Tools for Polymers and Multicomponent Polymeric Systems: New Trends, Challenges and Opportunities.....	1
<i>Jose James, K.P. Pramoda, and Sabu Thomas</i>	
<b>Chapter 2</b> Theoretical Aspects of Simultaneous Thermogravimetric Analysis (TGA) and Differential Thermal Analysis (DTA)/ Differential Scanning Calorimetry (DSC).....	11
<i>Siew Sand Chee, Mohammad Jawaid, and Mohamed Thariq</i>	
<b>Chapter 3</b> Application of TGA and DTA to Polymeric Systems (Neat Polymeric Systems) .....	37
<i>Dilipkumar Pal and Vinod Kumar Gurjar</i>	
<b>Chapter 4</b> Applications of TGA and DTA to Multicomponent Polymeric Systems Including Blends, IPNs, Composites.....	73
<i>Murugesan Shunmughanathan and Kasi Pitchumani</i>	
<b>Chapter 5</b> Multiphysics Modeling and Simulation of the Effective Thermal Conductivity of Polymeric Composites.....	119
<i>S.E. Ocheme and S.J. Antony</i>	
<b>Chapter 6</b> Application of DSC to Polymeric Systems .....	153
<i>Sanjay Remanan and Narayan Ch. Das</i>	
<b>Chapter 7</b> Theoretical Aspects of Dynamic Mechanical Analysis.....	175
<i>T.P. Mohan and K. Kanny</i>	
<b>Chapter 8</b> A Review on Dynamic Mechanical Properties of Polymer Nanocomposites .....	193
<i>T.A. Sajith, Azerai Ali Rahman, Zakiah Ahmad, and Sabu Thomas</i>	

v

Copyrighted material

vi

Contents

<b>Chapter 9</b> Dielectric Analysis: Main Concepts, Instrumentation, Basic Theoretical Analysis.....	203
<i>Ana Catarina Lima, C.M. Costa, and S. Lanceros-Méndez</i>	
<b>Chapter 10</b> Dielectric Analysis of Different Natural and Synthetic Polymer Types.....	217
<i>Hugo Salazar, Pedro M. Martins, C.M. Costa, and S. Lanceros-Méndez</i>	
<b>Chapter 11</b> Applications of Dielectric Analysis (DEA) to Multicomponent Polymeric Systems.....	245
<i>A.C. Patsidis and G.C. Psarras</i>	
<b>Index.....</b>	273

# 3 Application of TGA and DTA to Polymeric Systems (Neat Polymeric Systems)

*Dilipkumar Pal and Vinod Kumar Gurjar*

Guru Ghasidas Vishwavidyalaya (A Central University)

## CONTENTS

3.1	Thermal Analysis (TA).....	38
3.1.1	Introduction .....	38
3.1.2	Definition of TA.....	38
3.1.3	Fundamentals of TA .....	38
3.1.4	Techniques of TA.....	39
3.2	Thermogravimetry Analysis (TGA).....	39
3.2.1	Principle.....	39
3.2.2	Instrumentation.....	40
3.3	Measurements and Analyses .....	40
3.3.1	Designing and Performing a TGA Experiment.....	41
3.3.2	Low-Molecular-Mass Components in Polymers .....	44
3.3.3	Isothermal TGA Experiments .....	46
3.3.4	Loss of Volatile Reaction Products.....	47
3.4	Application of TGA .....	48
3.4.1	Compositional Analyses .....	50
3.4.2	Thermal Stability Studies .....	51
3.4.3	Polymer Thermal and Oxidative Stability.....	51
3.4.4	Degradation Studies.....	56
3.4.5	Complementary Pyrolysis Studies.....	57
3.4.6	Activation Energy .....	57
3.4.7	Polymer Transitions .....	58
3.4.8	Effect of Antioxidants on Polymer Ageing .....	58
3.4.9	Polymer Lifetime Measurements.....	58
3.4.10	Interpretation of TGA Curves .....	58
3.5	Differential Thermal Analysis (DTA) .....	60
3.5.1	Background.....	60
3.5.2	Principles of DTA .....	61
3.5.3	Instrumentation.....	62