

**HANDBOOK OF POLYMER
SYNTHESIS, CHARACTERIZATION,
AND PROCESSING**

HANDBOOK OF POLYMER SYNTHESIS, CHARACTERIZATION, AND PROCESSING

Edited by

ENRIQUE SALDÍVAR-GUERRA

Centro de Investigación en Química Aplicada
Saltillo Coahuila, México

EDUARDO VIVALDO-LIMA

Facultad de Química, Universidad Nacional Autónoma de México
Ciudad Universitaria, México, D.F., México

 **WILEY**

A JOHN WILEY & SONS, INC., PUBLICATION

Copyright © 2013 by John Wiley & Sons, Inc. All rights reserved

Published by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4470, or on the web at www.copyright.com. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permission>.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at www.wiley.com.

Library of Congress Cataloging-in-Publication Data:

Handbook of polymer synthesis, characterization, and processing / edited by Enrique Saldívar-Guerra, Centro de Investigación en Química Aplicada, Saltillo Coahuila, Mexico, Eduardo Vivaldo-Lima, Facultad de Química, Departamento de Ingeniería Química, Universidad Nacional Autónoma de México, México, D.F., México.

pages cm

Includes bibliographical references and index.

ISBN 978-0-470-63032-7 (cloth)

1. Polymerization. I. Saldívar-Guerra, Enrique, editor of compilation. II. Vivaldo-Lima, Eduardo, editor of compilation.

TP156.P6H36 2013

547'.28—dc23

2012025752

Printed in the United States of America

ISBN: 9780470630327

10 9 8 7 6 5 4 3 2 1

To Amparo, Adriana and Andrés, with love
To Adriana, Eduardo Abraham and Luis Ángel, with appreciation and love

CONTENTS

PREFACE	xv
ACKNOWLEDGMENTS	xvii
CONTRIBUTORS	xix
PART I BASIC CONCEPTS	1
1 Introduction to Polymers and Polymer Types	3
<i>Enrique Saldívar-Guerra and Eduardo Vivaldo-Lima</i>	
1.1 Introduction to Polymers	3
1.2 Classification of Polymers	8
1.3 Nomenclature	12
References	13
2 Polymer States and Properties	15
<i>J. Betzabe González-Campos, Gabriel Luna-Bárcenas, Diana G. Zárate-Triviño, Arturo Mendoza-Galván, Evgen Prokhorov, Francisco Villaseñor-Ortega, and Isaac C. Sanchez</i>	
2.1 Introduction	15
2.2 Glass Transition Temperature (α -Relaxation) Controversy in Chitin, Chitosan, and PVA	16
2.3 Glass Transition Related to the α -Relaxation	16
2.4 Moisture Content Effects on Polymer's Molecular Relaxations	17
2.5 Dielectric Fundamentals	18
2.6 Chitin, Chitosan, and PVA Films Preparation for Dielectric Measurements	21
2.7 Dielectric Relaxations in Chitin: Evidence for a Glass Transition	22
2.8 Dielectric Relaxations in Neutralized and Nonneutralized Chitosan: The Stronger Water Content Effect on the α -Relaxation and the Glass Transition Phenomenon	30
2.9 PVA Dielectric Relaxations	35
References	38

PART II	POLYMER SYNTHESIS AND MODIFICATION	41
3	Step-Growth Polymerization	43
	<i>Luis E. Elizalde, Gladys de los Santos-Villarreal, José L. Santiago-García, and Manuel Aguilar-Vega</i>	
3.1	Introduction	43
3.2	Polymerization Kinetics	46
3.3	Polyamides	48
3.4	Polyimides	50
3.5	Polyesters	50
3.6	Inorganic Condensation Polymers	53
3.7	Dendrimers	54
3.8	Thermoset Polycondensation Polymers	55
3.9	Controlled Molecular Weight Condensation Polymers	57
	References	62
4	Free Radical Polymerization	65
	<i>Ramiro Guerrero-Santos, Enrique Saldívar-Guerra, and José Bonilla-Cruz</i>	
4.1	Introduction	65
4.2	Basic Mechanism	66
4.3	Other Free Radical Reactions	68
4.4	Kinetics and Polymerization Rate	71
4.5	Molecular Weight and Molecular Weight Distribution	74
4.6	Experimental Determination of Rate Constants	76
4.7	Thermodynamics of Polymerization	77
4.8	Controlled Radical Polymerization	78
	References	81
5	Coordination Polymerization	85
	<i>João B. P. Soares and Odilia Pérez</i>	
5.1	Introduction	85
5.2	Polymer Types	87
5.3	Catalyst Types	87
5.4	Coordination Polymerization Mechanism	93
5.5	Polymerization Kinetics and Mathematical Modeling	93
	References	101
6	Copolymerization	105
	<i>Marc A. Dubé, Enrique Saldívar-Guerra, and Iván Zapata-González</i>	
6.1	Introduction	105
6.2	Types of Copolymers	106
6.3	Copolymer Composition and Microstructure	107
6.4	Reaction Conditions: Considerations	118
	References	121
7	Anionic Polymerization	127
	<i>Roderic Quirk</i>	
7.1	Introduction	127
7.2	Living Anionic Polymerization	127
7.3	General Considerations	129
7.4	Kinetics and Mechanism of Polymerization	134

7.5	Stereochemistry	144
7.6	Copolymerization of Styrenes and Dienes	148
7.7	Synthetic Applications of Living Anionic Polymerization	150
	References	157
8	Cationic Polymerizations	163
	<i>Filip E. Du Prez, Eric J. Goethals, and Richard Hoogenboom</i>	
8.1	Introduction	163
8.2	Carbocationic Polymerization	163
8.3	Cationic Ring-Opening Polymerization	172
8.4	Summary and Prospects	181
	Acknowledgment	181
	References	181
9	Crosslinking	187
	<i>Julio César Hernández-Ortiz and Eduardo Vivaldo-Lima</i>	
9.1	Introduction	187
9.2	Background on Polymer Networks	187
9.3	Main Chemical Routes for Synthesis of Polymer Networks	191
9.4	Characterization of Polymer Networks and Gels	193
9.5	Theory and Mathematical Modeling of Crosslinking	195
	Appendix A Calculation of Average Chain Length	200
	Appendix B Calculation of Sol and Gel Fractions	201
	Acknowledgments	202
	References	202
10	Polymer Modification: Functionalization and Grafting	205
	<i>José Bonilla-Cruz, Mariamne Dehonor, Enrique Saldívar-Guerra, and Alfonso González-Montiel</i>	
10.1	General Concepts	205
10.2	Graft Copolymers	207
	References	219
11	Polymer Additives	225
	<i>Rudolf Pfaendner</i>	
11.1	Introduction	225
11.2	Antioxidants	227
11.3	PVC Heat Stabilizers	231
11.4	Light Stabilizers	233
11.5	Flame Retardants	235
11.6	Plasticizers	238
11.7	Scavenging Agents	239
11.8	Additives to Enhance Processing	240
11.9	Additives to Modify Plastic Surface Properties	240
11.10	Additives to Modify Polymer Chain Structures	241
11.11	Additives to Influence Morphology and Crystallinity of Polymers	242
11.12	Antimicrobials	243
11.13	Additives to Enhance Thermal Conductivity	243
11.14	Active Protection Additives (Smart Additives)	243
11.15	Odor Masking	244

11.16	Animal Repellents	244
11.17	Markers	244
11.18	Blowing Agents	244
11.19	Summary and Trends in Polymer Additives	245
	References	245
	Further Reading	246
PART III POLYMERIZATION PROCESSES AND ENGINEERING		249
12	Polymer Reaction Engineering	251
	<i>Alexander Penlidis, Eduardo Vivaldo-Lima, Julio César Hernández-Ortiz, and Enrique Saldívar-Guerra</i>	
12.1	Introduction	251
12.2	Mathematical Modeling of Polymerization Processes	252
12.3	Useful Tips on Polymer Reaction Engineering (PRE) and Modeling	257
12.4	Examples of Several Free Radical (Co)Polymerization Schemes and the Resulting Kinetic and Molecular Weight Development	
	Equations	264
	Acknowledgments	270
	References	270
13	Bulk and Solution Processes	273
	<i>Marco A. Villalobos and Jon Debling</i>	
13.1	Definition	273
13.2	History	273
13.3	Processes for Bulk and Solution Polymerization	274
13.4	Energy Considerations	287
13.5	Mass Considerations	289
	References	292
14	Dispersed-Phase Polymerization Processes	295
	<i>Jorge Herrera-Ordóñez, Enrique Saldívar-Guerra, and Eduardo Vivaldo-Lima</i>	
14.1	Introduction	295
14.2	Emulsion Polymerization	295
14.3	Microemulsion Polymerization	303
14.4	Miniemulsion Polymerization	304
14.5	Applications of Polymer Latexes	304
14.6	Dispersion and Precipitation Polymerizations	305
14.7	Suspension Polymerization	305
14.8	Controlled Radical Polymerization (CRP) in Aqueous	
	Dispersions	308
	References	310
15	New Polymerization Processes	317
	<i>Eduardo Vivaldo-Lima, Carlos Guerrero-Sánchez, Christian H. Hornung, Irais A. Quintero-Ortega, and Gabriel Luna-Bárcenas</i>	
15.1	Introduction	317
15.2	Polymerizations in Benign or Green Solvents	317
15.3	Alternative Energy Sources for Polymerization Processes	327
15.4	Polymerization in Microreactors	329

Acknowledgments	331
References	331
PART IV POLYMER CHARACTERIZATION	335
16 Polymer Spectroscopy and Compositional Analysis	337
<i>Gladys de los Santos-Villarreal and Luis E. Elizalde</i>	
16.1 Introduction	337
16.2 Elemental Analysis	337
16.3 Infrared Spectroscopy	339
16.4 Nuclear Magnetic Resonance of Polymers in Solution	343
16.5 Mass Spectrometry	351
References	353
17 Polymer Molecular Weight Measurement	355
<i>María Guadalupe Neira-Velázquez, María Teresa Rodríguez-Hernández, Ernesto Hernández-Hernández, and Antelmo R. Y. Ruiz-Martínez</i>	
17.1 Introduction	355
17.2 Historical Background	355
17.3 Principles of GPC	356
17.4 Measurement of Intrinsic Viscosity	362
References	365
18 Light Scattering and its Applications in Polymer Characterization	367
<i>Roberto Alexander-Katz</i>	
18.1 Introduction	367
18.2 Principles of Static and Dynamic Light Scattering	367
18.3 Static Light Scattering by Dilute Polymer Solutions	370
18.4 Dynamic Light Scattering	377
References	387
19 Small-Angle X-Ray Scattering of Polymer Systems	391
<i>Carlos A. Avila-Orta and Francisco J. Medellín-Rodríguez</i>	
19.1 Introduction	391
19.2 Polymer Morphology	391
19.3 Small-Angle X-Ray Scattering	393
19.4 Analysis in Reciprocal Space	395
19.5 Analysis in Real Space	399
Appendix A Procedure to Obtain Morphological Data from 1D SAXS Profiles	404
References	406
20 Microscopy	409
<i>Mariamne Dehonor, Carlos López-Barrón, and Christopher W. Macosko</i>	
20.1 Introduction	409
20.2 Transmission Electron Microscopy	409
20.3 Three-Dimensional Microscopy	416
References	421

21	Structure and Mechanical Properties of Polymers	425
	<i>Manuel Aguilar-Vega</i>	
21.1	Structure of Polymer Chains	425
21.2	Mechanical Properties of Polymers	426
21.3	Mechanical Properties of Polymer Composites	431
	References	434
PART V	POLYMER PROCESSING	435
22	Polymer Rheology	437
	<i>Estanislao Ortíz-Rodríguez</i>	
22.1	Introduction to Polymer Rheology Fundamentals	437
22.2	Linear Viscoelasticity	440
22.3	Viscometric Techniques for Polymer Melts	441
22.4	Overview of Constitutive Equations	443
22.5	Brief Overview on Other Relevant Polymer Rheology Aspects	445
	References	448
23	Principles of Polymer Processing	451
	<i>Luis F. Ramos-de Valle</i>	
23.1	General	451
23.2	Compounding	451
23.3	Extrusion	452
23.4	Bottle Blowing	455
23.5	Injection Molding	455
23.6	Thermoforming	460
	References	461
	Further Reading	461
24	Blown Films and Ribbons Extrusion	463
	<i>Jorge R. Robledo-Ortíz, Daniel E. Ramírez-Arreola, Denis Rodrigue, and Rubén González-Núñez</i>	
24.1	Introduction	463
24.2	Extrusion Processes for Blown Films and Ribbons	463
24.3	Equations	465
24.4	Ribbon and Film Dimensions	467
24.5	Cooling Process and Stretching Force	467
24.6	Morphology and Mechanical Properties	469
	References	472
25	Polymer Solutions and Processing	473
	<i>Dámaso Navarro Rodríguez</i>	
25.1	Introduction	473
25.2	Polymer Solution Thermodynamics and Conformation of Polymer Chains: Basic Concepts	474
25.3	Semidilute Polymer Solutions	481
25.4	Processing of Polymer Solutions	482
	References	488

26	Wood and Natural Fiber-Based Composites (NFCs)	493
	<i>Jorge R. Robledo-Ortíz, Francisco J. Fuentes-Talavera, Rubén González-Núñez, and José A. Silva-Guzmán</i>	
26.1	Introduction	493
26.2	Background	493
26.3	Raw Materials	494
26.4	Manufacturing Process	497
26.5	Properties of Composite Materials	497
26.6	Durability	498
26.7	Factors that Affect Decay of Wood–Plastic Composites	500
26.8	Uses of Wood–Plastic Composites	501
	References	501
27	Polymer Blends	505
	<i>Saúl Sánchez-Valdes, Luis F. Ramos-de Valle, and Octavio Manero</i>	
27.1	Introduction	505
27.2	Miscibility in Polymer Blends	505
27.3	Compatibility in Polymer Blends	508
27.4	Techniques for Studying Blend Microstructure	509
27.5	Preparation of Polymer Blends	510
27.6	Factors Influencing the Morphology of a Polymer Blend	511
27.7	Properties of Polymer Blends	513
27.8	Applications of Polymer Blends	516
	References	517
28	Thermosetting Polymers	519
	<i>Jean-Pierre Pascault and Roberto J.J. Williams</i>	
28.1	Introduction	519
28.2	Chemistries of Network Formation	520
28.3	Structural Transformations During Network Formation	521
28.4	Processing	524
28.5	Conclusions	532
	References	532
PART VI	POLYMERS FOR ADVANCED TECHNOLOGIES	535
29	Conducting Polymers	537
	<i>María Judith Percino and Víctor Manuel Chapela</i>	
29.1	Introduction	537
29.2	Historical Background	538
29.3	The Structures of Conducting Polymers	539
29.4	Charge Storage	539
29.5	Doping	541
29.6	Polyanilines	543
29.7	Charge Transport	544
29.8	Syntheses	545
29.9	Conducting Polymers	545
29.10	Characterization Techniques	551
29.11	Present and Future Potential	552
	References	555

30 Dendritic Polymers	559
<i>Jason Dockendorff and Mario Gauthier</i>	
30.1 Introduction	559
30.2 Dendrimers	561
30.3 Hyperbranched Polymers	567
30.4 Dendrigraft Polymers	574
30.5 Concluding Remarks	581
References	582
31 Polymer Nanocomposites	585
<i>Octavio Manero and Antonio Sanchez-Solis</i>	
31.1 Introduction	585
31.2 Polyester/Clay Nanocomposites	586
31.3 Polyolefin/Clay Nanocomposites	590
31.4 Polystyrene/Clay Nanocomposites	593
31.5 Polymer/Carbon Black Nanocomposites	596
31.6 Nanoparticles of Barium Sulfate	597
31.7 Polymer/Graphene Nanocomposites	598
31.8 Conclusions	601
Acknowledgments	601
References	601
INDEX	605

PREFACE

The industry of polymers is very complex, in part because it encompasses many aspects that are of multidisciplinary nature. The chain of production of polymers requires expert knowledge in different areas: (i) polymer synthesis, both from the chemistry and the engineering aspects; (ii) polymer characterization, including chemical, physicochemical, rheological properties and others; and (iii) polymer processing and transformation into final products.

The aim of this handbook is to serve as the first source and comprehensive reference to all aspects of interest in the polymer industry. Given the complexity of this industry and the specialized knowledge required in each area of polymer production and application, most of the books dealing with polymer science and technology cover only some aspects of the polymer production chain; however, we believe that a professional working in the polymer industry or, in general, in polymer science and technology would greatly benefit from a book summarizing all the aspects involved in the production chain of the polymer industry. The book has been written with the underlying idea of meeting this need. An effort has been made in every chapter to include the fundamentals of the chapter's subject, the relevant literature, and the new trends in the field.

The book is addressed mainly to professionals in virtually all positions in the polymer industry: manufacturing, quality control, R&D, sales, technical assistance, and so on. Another group of potential readers is the undergraduate and graduate students in fields related to polymer science and technology. Finally, academic researchers of universities and institutes, working in different areas of polymerization and polymers, will find the book useful for expanding their knowledge beyond their area of expertise. The book can be used to establish the first approach to a specific topic by anyone in the target audience, to broaden the knowledge

of industrial practitioners wanting to know more about the polymer production chain, and to look for references in order to deepen the understanding of specialized aspects of a topic. It can also be used as a textbook in the first course in polymer science or engineering, at the undergraduate or graduate level, especially if a broad coverage of the field is desired.

After an introduction to the basic concepts of polymers and polymerization (Chapter 1) and thermodynamic polymer states (Chapter 2)¹, the second part of the handbook is devoted to the main synthesis techniques of polymers (Chapters 3–5 and 7–8), including chapters covering concepts that may be applicable to all the synthesis techniques (crosslinking and grafting in Chapters 9 and 10, respectively). The important subject of copolymers (Chapter 6) is also included in this section, as synthesis and structure are closely related areas. The subject of additives is included in the synthesis section because, from the point of view of properties and applications, they have become an important part of the polymeric material being synthesized. The third part of the handbook is dedicated to the engineering principles and the different types of polymerization processes used in industry (Chapters 12–14); the new trends, from an engineering perspective, are also discussed (Chapter 15). Part IV, which includes Chapters 16–21, provides the scope of the main techniques used for polymer characterization and testing, at both the fundamental and the applied levels. Chapters 22–28 cover polymer processing principles, techniques, and equipment. Chapter 28 (Thermosetting Polymers) is included here because of the emphasis on industrial processes, although it implies simultaneous reaction and shaping. Finally, Chapters 29–31 deal with advanced

¹Some important thermodynamic concepts related to polymers are dealt with in Chapter 25.

and more specialized subjects in the polymer field, which are of increasing importance (nanomaterials, dendrimers, and conjugated polymers).

The handbook represents the joint effort of a large number of scientists and researchers working in the many

diverse fields of polymer science and technology. Many years of study and experience have been put together in an organized manner in this work; hopefully, the handbook will serve its purpose with a large audience.

ACKNOWLEDGMENTS

We are deeply grateful to the authors of all the chapters for their contribution and for sharing their expert knowledge. We also thank the Wiley-Blackwell editors and team for their support and guidance throughout the writing and editing of the handbook.

We also thank the several sponsors who have allowed us to carry out fundamental and applied research to an extent where we feel that we have added a few salt grains to the polymer science and engineering fields. E.V.-L. is indebted

to UNAM (PAIP and PAPIIT Project 119510), CONACyT (Project 101682), and ICyTDF (Project PICSA11-56). E.S.-G. acknowledges CIQA and CONACyT for continuous support.

Last but not least, we thank our families for their support and understanding during the editing of the handbook, and to some of our students and office staff at CIQA and FQ-UNAM for taking some extra work load that allowed us to invest time in this project.

CONTRIBUTORS

Manuel Aguilar-Vega, Materials Unit, Membranes Laboratory, Centro de Investigación Científica de Yucatán, Mérida, Yucatán, México

Roberto Alexander-Katz, Departamento de Física, Universidad Autónoma Metropolitana-Iztapalapa, Col. Vicentina, Mexico

Carlos A. Avila-Orta, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México

José Bonilla-Cruz, Centro de Investigación en Materiales Avanzados, Apodaca, Nuevo León, México

Víctor Manuel Chapela, Laboratorio de Polímeros, Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla, Puebla, Pue., México

Jon Debling, BASF Corp., Wyandotte, MI, USA

Mariamne Dehonor, Macro-M S.A. de C.V. Lerma, Edo. de México, México

Jason Dockendorff, Department of Chemistry, Institute for Polymer Research, University of Waterloo, Waterloo, Ontario, Canada

Filip E. Du Prez, Department of Organic Chemistry, Polymer Chemistry Research group, Ghent University, Ghent, Belgium

Marc A. Dubé, Department of Chemical and Biological Engineering, Centre for Catalysis Research and Innovation, University of Ottawa, Ottawa, Ontario, Canada

Luis E. Elizalde, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México

Francisco J. Fuentes-Talavera, Departamento de Madera, Celulosa y Papel, Universidad de Guadalajara, Las Agujas, Zapopan, Jalisco, México

Mario Gauthier, Department of Chemistry, Institute for Polymer Research, University of Waterloo, Waterloo, Ontario, Canada

Eric J. Goethals, Department of Organic Chemistry, Polymer Chemistry Research group, Ghent University, Ghent, Belgium

J. Betzabe González-Campos, Universidad Michoacana de San Nicolás de Hidalgo, Instituto de Investigaciones Químico-Biológicas, Morelia, Michoacán, México

Alfonso González-Montiel, Macro M S.A. de C.V. Lerma, Edo. De México, México

Rubén González-Núñez, Departamento de Ingeniería Química, Universidad de Guadalajara, Guadalajara, Jalisco, México

Carlos Guerrero-Sánchez, CSIRO, Materials Science and Engineering Division, Victoria, Australia

Ramiro Guerrero-Santos, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México

Ernesto Hernández-Hernández, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México

Julio César Hernández-Ortiz, Departamento de Ingeniería Química, Facultad de Química, Universidad Nacional Autónoma de México, México D.F., México

Jorge Herrera-Ordóñez, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México

- Richard Hoogenboom**, Department of Organic Chemistry, Supramolecular Chemistry group, Ghent University, Ghent, Belgium
- Christian H. Hornung**, CSIRO, Materials Science and Engineering Division, Victoria, Australia
- Carlos López-Barrón**, Center for Neutron Science, Department of Chemical and Biomolecular Engineering, University of Delaware, Newark, DE, USA
- Gabriel Luna-Bárceñas**, Centro de Investigación y de Estudios Avanzados (CINVESTAV) del IPN, Unidad Querétaro, Querétaro, Querétaro, México
- Christopher W. Macosko**, Dept. of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, MN, USA
- Octavio Manero**, Instituto de Investigaciones en Materiales, Universidad Nacional Autónoma de México, México D.F., México
- Francisco J. Medellín-Rodríguez**, Facultad de Ciencias Químicas, Universidad Autónoma de San Luis Potosí, San Luis Potosí, San Luis Potosí, México
- Arturo Mendoza-Galván**, Centro de Investigación y de Estudios Avanzados (CINVESTAV) del IPN, Unidad Querétaro, Querétaro, Querétaro, México
- Dámaso Navarro Rodríguez**, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México
- María Guadalupe Neira-Velázquez**, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México
- Estanislao Ortiz-Rodríguez**, A. Schulman de México, San Luis Potosí, México
- Jean-Pierre Pascault**, Université de Lyon, UMR-CNRS 5223, INSA-Lyon, Ingénierie des Matériaux Polymères/Laboratoire des Matériaux Macromoléculaires, Villeurbanne, France
- Alexander Penlidis**, Department of Chemical Engineering, Institute for Polymer Research (IPR), University of Waterloo, Waterloo, Ontario, Canada
- María Judith Percino**, Laboratorio de Polímeros, Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla, Puebla, Pue., México
- Odilia Pérez**, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México
- Rudolf Pfaendner**, Fraunhofer Institute for Structural Durability and System Reliability LBF, Division Plastics, Darmstadt, Germany
- Evgen Prokhorov**, Centro de Investigación y de Estudios Avanzados (CINVESTAV) del IPN, Unidad Querétaro, Querétaro, Querétaro, México
- Iraís A. Quintero-Ortega**, División de Ciencias e Ingenierías, Universidad de Guanajuato, León, México
- Roderic Quirk**, Dept. of Polymer Science, The University of Akron, Akron, OH, USA
- Daniel E. Ramírez-Arreola**, Departamento de Ingenierías, Universidad de Guadalajara, Autlán de Navarro, Jalisco, México
- Jorge R. Robledo-Ortíz**, Departamento de Madera, Celulosa y Papel, Universidad de Guadalajara, Las Agujas, Zapopan, Jalisco, México
- Denis Rodrigue**, Department of Chemical Engineering and CERMA, Université Laval, Quebec City, Quebec, Canada
- María Teresa Rodríguez-Hernández**, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México
- Antelmo R. Y. Ruiz-Martínez**, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México
- Enrique Saldívar-Guerra**, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México
- Isaac C. Sanchez**, Chemical Engineering Department, The University of Texas at Austin
- Antonio Sanchez-Solis**, Instituto de Investigaciones en Materiales, Universidad Nacional Autónoma de México, México D.F., México
- José L. Santiago-García**, Materials Unit, Membranes Laboratory, Centro de Investigación Científica de Yucatán, Mérida, Yucatán, México
- Gladys de los Santos-Villarreal**, Centro de Investigación en Química Aplicada, Saltillo, Coahuila, México
- José A. Silva-Guzmán**, Departamento de Madera, Celulosa y Papel, Universidad de Guadalajara, Las Agujas, Zapopan, Jalisco, México
- João B. P. Soares**, Department of Chemical Engineering, University of Waterloo, Waterloo, Ontario, Canada
- Saúl Sánchez-Valdes**, Centro de Investigación en Química Aplicada, Saltillo, México
- Luis F. Ramos-de Valle**, Centro de Investigación en Química Aplicada, Saltillo, México
- Marco A. Villalobos**, Cabot Corp., Billerica, MA, USA
- Francisco Villaseñor-Ortega**, Department of Biochemical Engineering, Instituto Tecnológico de Celaya, Celaya, Guanajuato, México
- Eduardo Vivaldo-Lima**, Departamento de Ingeniería Química, Facultad de Química, Universidad Nacional Autónoma de México, México, D.F., México

Roberto J. J. Williams, Institute of Materials Science and Technology (INTEMA), University of Mar del Plata and National Research Council (CONICET), Mar del Plata, Argentina

Iván Zapata-González, Facultad de Ciencias Químicas, Universidad Autónoma de Coahuila, Saltillo, Coahuila, México

Diana G. Zárate-Triviño, Centro de Investigación y de Estudios Avanzados (CINVESTAV) del IPN, Unidad Querétaro, Querétaro, Querétaro, México