# Handbook of Polymers for Pharmaceutical Technologies

**Scrivener Publishing**
100 Cummings Center, Suite 541J
Beverly, MA 01915-6106

*Publishers at Scrivener*
Martin Scrivener(martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

# Handbook of Polymers for Pharmaceutical Technologies

## Volume 2
## Processing and Applications

Edited by

**Vijay Kumar Thakur and**
**Manju Kumari Thakur**


WILEY

Co-published by John Wiley & Sons, Inc. Hoboken, New Jersey, and Scrivener Publishing LLC, Salem, Massachusetts.
Published simultaneously in Canada.



Cover design by Russell Richardson

***Library of Congress Cataloging-in-Publication Data:***

ISBN 978-1-119-04138-2

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

*To my parents and teachers who helped me become what I am today.*

Vijay Kumar Thakur

# Contents

# Preface

The modern pharmaceutical market is under relentless pressure from slowing new drug product approvals, blockbuster drug patent expiry, price pressure and global competition. In addition, new opportunities exist due to an evolving patient population, numerous unmet medical needs and growing disease awareness. In order to sustain performance, the pharmaceutical industry must evolve and improve product development and processing efficiencies. Therefore, efficient and cost-effective product development and processing are continually being explored to meet the challenge of not only reducing cost, but also the risk of product recalls. In the last few decades, much importance has been given to the use of polymers in pharmaceutical systems. Huge opportunities in the design, synthesis and modification of the physical and chemical properties of polymers have made them the most rapidly growing group of materials with great importance and possible applications in pharmacy, medicine and cosmetology. Polymeric materials having biomedical applications can be classified into different groups depending upon the application. For example, they are generally divided into two major groups according to use: those employed in prosthetic devices such as cardiovascular and orthopedic prostheses; and those employed as therapeutic systems such as drug carriers. Among the prosthetic systems, polymeric materials can be used as coatings or as cemented prostheses. Some of the major advantages in using polymeric materials for biomedical applications are their flexibility, biocompatibility, the possibility of tailoring their mechanical properties and their ability to incorporate therapeutic agents into their matrix in order to allow drug administration at a specific site.

Both natural and man-made polymers have been widely utilized as tablet binders and filler-binders in the pharmaceutical industry. The physico-chemical and mechanical properties such as particle size, shape and deformation behavior of polymeric binders are key to their effective use. Polymeric membranes are also becoming increasingly important in the field of separation processes in the pharmaceutical industry and artificial organs. Some polymers are obtained from natural sources (natural polymer) and then chemically modified for various applications, while others are chemically synthesized (synthetic polymer). Polymeric membranes can be fabricated in different configurations, such as flat sheet, tubular hollow fibers, nanofibers, etc., via different techniques. Since the performance of the membrane is largely controlled by its surface (active layer), the design of membrane surface and its characterization, either by chemistry or morphology, are extremely important. Hence, emphasis is being placed on the membrane surface. Hot-melt extrusion (HME) technique is used to create a dispersion of the active pharmaceutical ingredient (API) in a polymer matrix in order to achieve solubility enhancement, release rate modulation, mask taste, or to develop a new dosage form. However, polymers must fulfill a number of requirements in order to be suitable for HME processing. The relatively recent introduction of

HME in the pharmaceutical industry has opened new areas of applications for old and newly synthesized polymers, and enabled drug manufacturers to scale up the production of solid dispersions. A variety of chemically diverse polymers with different physico-chemical properties are available, which enable formulators to fine-tune the solid form of the extruded product by the selection of suitable polymer, drug-polymer ratio and operating conditions. Scientists in collaboration with pharmaceutical industries are extensively developing new classes of pharmaceutical materials. This second volume of *Handbook of Polymers for Pharmaceutical Technologies* is primarily focused on the pharmaceutical polymers and deals with the processing and applications of these polymers. Numerous critical issues and suggestions for future work are comprehensively discussed in this book with the hope that it will provide a deep insight into the state-of-art of pharmaceutical polymers. The prime topics extensively described in this book include: particle engineering of polymers into multifunctional interactive excipients; the art of making polymeric membranes; pharmaceutical applications of polymeric membranes; development of microstructuring technologies of polycarbonate for establishing advanced cell cultivation systems; *in-situ* gelling thermosensitive hydrogels for protein delivery applications; polymers as formulation excipients for the hot-melt extrusion processing of pharmaceuticals; poly lactic-co-glycolic acid (PLGA) copolymer and its pharmaceutical application; application of PVC in construction of ion-selective electrodes for pharmaceutical analysis; a review of polymer electrodes for nonsteroidal, anti-inflammatory drugs; synthesis and preservation of polymer nanoparticles for pharmaceutical applications; pharmaceutical applications of maleic anhydride/acid copolymers; stimuli-sensitive polymeric nanomedicines for cancer imaging and therapy; artificial intelligence techniques used for modeling of processes involving polymers for pharmaceutical applications; a review of current pharmaceutical applications of polysiloxanes (silicones); polymer-doped nano-optical sensors for pharmaceutical analysis; and finally, polymer-based augmentation of immunosuppressive formulations – application of polymer technology in transplant medicine.

Several critical issues and suggestions for future work are comprehensively discussed in this book with the hope that it will provide a deep insight into the state-of-art of processing and applications of pharmaceutical polymers. We would like to thank the publisher and Martin Scrivener for their invaluable help in the organization of the editing process. Finally, we would like to thank our parents for their continuous encouragement and support.

**Vijay Kumar Thakur, PhD**
**Washington State University, USA**

**Manju Kumari Thakur, MSc, MPhil, PhD**
**Himachal Pradesh University, Shimla, India**
**May 2015**

# About the Editors

**Vijay Kumar Thakur, Ph.D.**

Email: vijayisu@hotmail.com

Dr. Vijay Kumar Thakur has been working as Research Faculty (staff scientist) in the School of Mechanical and Materials Engineering at Washington State University, USA, since September 2013. His former appointments include being a research scientist in Temasek Laboratories at Nanyang Technological University, Singapore, and a visiting research fellow in the Department of Chemical and Materials Engineering at LHU-Taiwan. His research interests include the synthesis and processing of biobased polymers, nanomaterials, polymer micro/nanocomposites, nanoelectronic materials, novel high dielectric constant materials, electrochromic materials for energy storage, green synthesis of nanomaterials, and surface functionalization of polymers/nanomaterials. He did his post doctorate in Materials Science at Iowa State University and his PhD in Polymer Science (2009) at the National Institute of Technology. In his academic career, he has published more than 80 SCI journal research articles in the field of polymers/materials science and holds one United States patent. He has also published 15 books and thirty book chapters on the advanced state-of-the-art of polymers/materials science with numerous publishers.

**Manju Kumari Thakur, M.Sc., M.Phil., Ph.D.**

Email: shandilyamn@gmail.com

Dr. Manju Kumar Thakur has been working as an Assistant Professor of Chemistry at the Division of Chemistry, Govt. Degree College Sarkaghat Himachal Pradesh University, Shimla, India, since June 2010. She received her BSc in Chemistry, Botany and Zoology; MSc, MPhil in Organic Chemistry and PhD in Polymer Chemistry from the Chemistry Department at Himachal Pradesh University, Shimla, India. She has rich experience in the field of organic chemistry, biopolymers, composites/nanocomposites, hydrogels, applications of hydrogels in the removal of toxic heavy metal ions, drug delivery, etc. She has published more than 30 research papers in several international journals, co-authored five books and has also published 25 book chapters in the field of polymeric materials.