ELSEVIER

Edited by
Sabu Thomas
Robert Shanks
Sarathchandran Chandrasekharakurup

NANOSTRUCTURED POLYMER BLENDS

Micro & Nano Technologies Series

Nanostructured Polymer Blends

Editors

Sabu Thomas

Robert Shanks

Sarathchandran Chandrasekharakurup

ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
William Andrew is an imprint of Elsevier

William Andrew is an imprint of Elsevier
225 Wyman Street, Waltham, MA 02451, USA
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

Notice
Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods or professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

Library of Congress Cataloging-in-Publication Data
A catalogue record for this book is available from the Library of Congress.

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

ISBN: 978-1-4557-3159-6

Typeset by MPS Limited, Chennai, India
www.adi-mps.com

Nanostructured Polymer Blends

Preface

Polymer blends are an effective means of combining polymers to obtain desirable properties from each constituent polymer without preparation of specific copolymers. Polymer blends are preferably two-phase materials so that properties of constituent polymers are retained, while in miscible polymers properties are likely to be averaged. In concert with interest in nanotechnology, the phase dimensions of a dispersed phase in polymer blends can vary from micrometer, to nanometer through to miscibility on a molecular scale. Polymer blends with nanometer dispersed phase are the subject of this book.

Nanostructured polymer blends have been classified into various combinations, polymer types and methods of preparation in developing the chapters of this book. Important questions to be addressed are: How can phase dimensions be created in the nanometer scale when polymers are in blends? Will a nanophase blend undergo particle growth through diffusion to form larger particles? Are special dispersion methods required or can the blends be created by phase separation from an initially miscible blend? Characterization techniques are available to assess structure, morphology and properties of nanostructured polymer blends.

Phase morphology in nanostructured blends could be obtained by shear dispersion of the minor phase if relative viscosity and interfacial tension was such that droplets are disrupted into smaller and smaller size until nano-dimensions are reached. Polymers that are miscible at elevated temperature could be cooled giving spinodal decomposition into a dispersed nano-phase. Phase separation by crosslinking of one polymer component will entropically separate the other polymer, particularly at the gel point, which may be accompanied by spinodal decomposition. Crystallization of one polymer will exclude and hence separate the second polymer. If kinetics and thermodynamics are suitable a nanostructured polymer blend can be formed. Theoretical modeling based upon solubility parameters, interactions parameters and volume fraction theories are applicable for an understanding of nanostructured polymer blends.

Nano-phase formation and stability can be achieved through use of compatibilisers since the interface is critical in dispersed particle stabilization. Blends where both polymers are thermoplastics are a convenient starting place for investigation of nanostructured blend formation. Thermosetting polymers combined with block copolymers gives potential for control of morphologies via block copolymer design and the time–temperature–transformation of the thermosetting polymer. If the copolymer is of hyper-branched type then further options are available for phase separation during cure of the thermoset. Combinations of block copolymers allow fine tuning of blend morphology by choice, arrangement and molar mass of the respective polymer blocks.

Specialty polymers such as hydrogels and liquid crystalline polymers can form nanophases due to gel structures or mesogen domains within one of the phases. Hybrid materials consisting of a disparity of size, source or composition can evolve into nanostructured materials with unique property combinations. The materials may have specific interfaces leading to explicit thin film properties, hierarchal structures and stimulus responsive character. Formation of a percolation network or co-continuous structure can impart electrical conductivity. Nano-polymer particles dispersed in a polymer can have a disproportionate role in thermal ageing due to polymer ageing dependence on free volume contributions. A further contribution is retardation of degradation as found for nano-composites and fire retardation. Polymer blend systems with controlled dispersed phase size and morphology in the nano-scale are being developed as part of the thrust into nano-materials. Unique property combinations and specificity are leading these materials into new applications with commercial development to follow.

Sabu Thomas
Robert Shanks
Sarathchandran Chandrasekharakurup

List of Contributors

Blessing Atim Aderibigbe Tshwane University of Technology, Department of Polymer Technology, Lynnwoodridge, Republic of South Africa

Gizelda Maria Alves Laboratory of Polymers, Chemical Engineering Department, Engineering School of Lorena, University of São Paulo, São Paulo, Brazil

S.M. Ashraf Materials Research Laboratory, Department of Chemistry, Jamia Millia Islamia (A Central University), New Delhi, India

Luigi Botta Department of Civil, Environmental, Aerospace, and Material Engineering, University of Palermo, Palermo, Italy

Shanavas Abdul Jailani Tshwane University of Technology, Department of Polymer Technology, Lynnwoodridge, Republic of South Africa

Jaragula Jayaramudu Tshwane University of Technology, Department of Polymer Technology, Lynnwoodridge, Republic of South Africa

Golap Kalita Department of Frontier Materials, Center for Fostering Young and Innovative Researchers, Nagoya Institute of Technology, Nagoya, Japan

Antonella Macagnano Institute for Microelectronics and Microsystems–National Research Council, Rome, Italy

Simone de Fátima Medeiros Laboratory of Polymers, Chemical Engineering Department, Engineering School of Lorena, University of São Paulo, São Paulo, Brazil

Yuan Meng MOE Key Laboratory of Macromolecular Synthesis and Functionalization, Department of Polymer Science and Engineering, Zhejiang University, Hangzhou China

Sérgio Roberto Montoro Laboratory of Polymers, Chemical Engineering Department, Engineering School of Lorena, University of São Paulo, São Paulo, Brazil

Koduri Ramam Department of Materials Engineering, Faculty of Engineering, University of Concepción, Concepción, Chile

Goddeti Siva Mohan Reddy Tshwane University of Technology, Department of Polymer Technology, Lynnwoodridge, Republic of South Africa

Ufana Riaz Materials Research Laboratory, Department of Chemistry, Jamia Millia Islamia (A Central University), New Delhi, India

Dr. Juan Rodríguez-Hernández Institute of Polymer Science and Technology (ICTP-CSIC), Chemistry and Properties of Polymeric Materials Department, Madrid, Spain

Emmanuel Rotimi Sadiku Department of Chemical and Metallurgical Engineering, Polymer Technology Division, Tshwane University of Technology, Republic of South Africa

Gity Mir Mohamad Sadeghi Department of Polymer Engineering and Color Technology, Amirkabir University of Technology, Tehran, Iran

Oluranti Sadiku-Agboola Tshwane University of Technology, Department of Chemical, Metallurgical and Material Engineering, Pretoria, Republic of South Africa
Emmanuel Rotimi Sadiku Tshwane University of Technology, Department of Chemical, Metallurgical and Material Engineering, Pretoria, Republic of South Africa
Rotimi Sadiku Tshwane University of Technology, Department of Polymer Technology, Lynnwoodridge, Republic of South Africa
Sarathchandran Chandrasekharakurup Centre for Nanoscience and Nanotechnology, Mahatma Gandhi University, Kottayam, Kerala, India
Roberto Scaffaro Department of Civil, Environmental, Aerospace, and Material Engineering, University of Palermo, Palermo, Italy
Robert A. Shanks Applied Sciences, RMIT University, Melbourne, Australia
Elijah Sobalaje Ogunniran Department of Chemical and Metallurgical Engineering, Polymer Technology Division, Tshwane University of Technology, Republic of South Africa
Masaki Tanemura Department of Frontier Materials, Nagoya Institute of Technology, Nagoya, Japan
Sabu Thomas Centre for Nanoscience and Nanotechnology, Mahatma Gandhi University, Kottayam, Kerala, India
Masayoshi Umeno Department of Electronics and Information Engineering, Chubu University, Kasugai, Japan
Kokkarachedu Varaprasad Tshwane University of Technology, Department of Polymer Technology, Lynnwoodridge, Republic of South Africa
Xinghong Zhang MOE Key Laboratory of Macromolecular Synthesis and Functionalization, Department of Polymer Science and Engineering, Zhejiang University, Hangzhou China

Contents