

MOLECULAR CHARACTERIZATION OF COMPOSITE INTERFACES

POLYMER SCIENCE AND TECHNOLOGY

Editorial Board:

William J. Bailey, *University of Maryland, College Park, Maryland*

J. P. Berry, *Rubber and Plastics Research Association of Great Britain,
Shawbury, Shrewsbury, England*

A. T. DiBenedetto, *The University of Connecticut, Storrs, Connecticut*

C. A. J. Hoeve, *Texas A & M University, College Station, Texas*

Yoichi Ishida, *Osaka University, Toyonaka, Osaka, Japan*

Frank E. Karasz, *University of Massachusetts, Amherst, Massachusetts*

Oslas Solomon, *Franklin Institute, Philadelphia, Pennsylvania*

Recent volumes in the series:

- Volume 16 POLYMERIC SEPARATION MEDIA
Edited by Anthony R. Cooper
- Volume 17 POLYMER APPLICATIONS OF RENEWABLE-RESOURCE MATERIALS
Edited by Charles E. Carraher, Jr., and L. H. Sperling
- Volume 18 REACTION INJECTION MOLDING AND FAST POLYMERIZATION REACTIONS
Edited by Jiri E. Kresta
- Volume 19 COORDINATION POLYMERIZATION
Edited by Charles C. Price and Edwin J. Vandenberg
- Volume 20 POLYMER ALLOYS III: Blends, Blocks, Grafts, and Interpenetrating Networks
Edited by Daniel Klempner and Kurt C. Frisch
- Volume 21 MODIFICATION OF POLYMERS
Edited by Charles E. Carraher, Jr., and James A. Moore
- Volume 22 STRUCTURE. PROPERTY RELATIONSHIPS OF POLYMERIC SOLIDS
Edited by Anne Hiltner
- Volume 23 POLYMERS IN MEDICINE: Biomedical and Pharmacological Applications
Edited by Emo Chiellini and Paolo Giusti
- Volume 24 CROWN ETHERS AND PHASE TRANSFER CATALYSIS IN POLYMER SCIENCE
Edited by Lon J. Mathias and Charles E. Carraher, Jr.
- Volume 25 NEW MONOMERS AND POLYMERS
Edited by Bill M. Culbertson and Charles U. Pittman, Jr.
- Volume 26 POLYMER ADDITIVES
Edited by Jiri E. Kresta
- Volume 27 MOLECULAR CHARACTERIZATION OF COMPOSITE INTERFACES
Edited by Hatsuo Ishida and Ganesh Kumar

A Continuation Order Plan is available for this series. A continuation order will bring delivery of each new volume immediately upon publication. Volumes are billed only upon actual shipment. For further information please contact the publisher.

MOLECULAR CHARACTERIZATION OF COMPOSITE INTERFACES

Edited by

Hatsuo Ishida

*Case Western Reserve University
Cleveland, Ohio*

and

Ganesh Kumar

*Vistakon Inc. (a Johnson & Johnson Company)
Jacksonville, Florida*

Springer Science+Business Media, LLC

Library of Congress Cataloging in Publication Data

Symposium on Polymer Composites.

Molecular characterization of composite interfaces.

(Polymer science and technology; v. 27)

"Proceedings of the Symposium on Polymer Composites: Interfaces, held at the American Chemical Society meeting in March 1983, in Seattle, Washington"—T.p. verso.

Bibliography: p.

Includes index.

1. Polymeric composites—Congresses. 2. Surface chemistry—Congresses. I. Ishida, Hatsuo. II. Kumar, Ganesh. III. American Chemical Society. Meeting (185th: 1983: Seattle, Wash.) IV. Title. V. Series.

TA418.9.C6S93 1983

620.1'18

84-20648

ISBN 978-1-4899-2253-3

ISBN 978-1-4899-2251-9 (eBook)

DOI 10.1007/978-1-4899-2251-9

Proceedings of the Symposium on Polymer Composites: Interfaces, held at the American Chemical Society meeting in March 1983, in Seattle, Washington

© 1985 Springer Science+Business Media New York
Originally published by Plenum Press, New York in 1985
Softcover reprint of the hardcover 1st edition 1985

All rights reserved

No part of this book may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, microfilming, recording, or otherwise, without written permission from the Publisher

PREFACE

This book is an extended version of the proceedings of the Symposium on Polymer Composites, Interfaces, which was held under the auspices of the Division of Polymer Chemistry, American Chemical Society (ACS) during the annual ACS meeting in Seattle, March, 1983.

The importance of the interface in composite materials has been recognized since the inception of modern composite technology. Specifically, silane coupling agents were developed for glass fiber reinforced composites at a very early date. Ever since then the diversity of composite materials and the development of various surface treatment methods have led to the establishment of an "interface art." A trial-and-error approach has dominated the interfacial aspects of composite technology until very recently. With the advent of modern analytical techniques for surface characterization, it became possible to study detailed surface and interface structures.

It was hoped that this symposium would catalyze such a fundamental and scientific approach in composite studies. For this reason, the symposium was structured to verify the influence of interfacial structures on the mechanical and physical performance of composites and to improve our knowledge of the microstructure of composite interfaces. As the word "composite" indicates, interdisciplinary interaction is indispensable for proper understanding of multiphase systems.

The symposium consisted of four sessions each of which is represented by the titles in Part II through Part V. However, in order to provide a rather in depth introduction to the field, some papers are rearranged into Part I, general overviews. All papers are reviewed by leading scientists in this field with standards similar to those of well-respected journals. The rest of this volume is divided into: Part II. Influence on Physical Properties; Part III. Structure of Coupling Agents and Interfaces; Part IV. Influence on Matrix Structure; and Part V.

Surfaces of Reinforcements. These divisions are instrumental in identifying the dominant structural factors. True understanding of the role of the interface, however, must come from an intricate combination of the findings made for each region.

This book is an important addition to the field since little has been written on the subject. It should be useful for those who want to manufacture more reproducible and reliable composites. For beginners, this may provide a milestone as the book represents the forefront of the field. The book discusses composites made of glass fibers, carbon fibers, organic fibers and particulate fillers. Characterization techniques include FT-IR, NMR, ESCA, ESR, SIMS, emission, microbalance and others. It is tempting to imagine that the knowledge accumulated with all these techniques will soon be used to control and tailor the interfacial structures required for specific composite properties.

No book is complete without making proper acknowledgement to those deserving it. We are grateful to the Polymer Chemistry Division and ACS for encouraging us to organize the symposium. Anonymous reviewers are the judge of high standards. Their hidden effort and help must be highly praised. Special thanks are due to Mr. R.T.Graf, S.R.Culler and J.D.Miller for careful proof reading of many of the manuscripts. We are very thankful for Ms. D.Waldron for typing the manuscripts in spite of the heart-breaking tragedy in her family during the entire period of the preparation of this book. Many thanks are also due to the interest in our project and the patience of Mr. P.J.Alvarez of Plenum Publishing Co. Whole-hearted support of our family members is always special to us. We wish that someday our children will advance beyond this milestone. As long as this book remains, the authors' commitment in their scientific pursuit will be remembered. Their cooperation and encouragement are gratefully acknowledged.

H.Ishida

G.Kumar

Department of Macromolecular Science
Case Western Reserve University
Cleveland, Ohio 44106

Vistacon Inc.
P.O.Box 10157
Jacksonville, Florida 32247

CONTENTS

PART I. GENERAL OVERVIEWS

| | |
|--|----|
| The Role of the Interface in Polymer Composites-Some Myths, Mechanisms and Modifications J.L.Kardos..... | 1 |
| Bonding Through Coupling Agents E.P.Plueddemann..... | 13 |
| Structural Gradient in the Silane Coupling Agent Layers and Its Influence on the Mechanical and Physical Properties of Composites H.Ishida..... | 25 |
| Surface Modification of Calcium Carbonate for Polymer Composites T.Nakatsuka..... | 51 |

PART II. INFLUENCE ON PHYSICAL PROPERTIES

| | |
|---|-----|
| Osmotic Pressure-Filled Cracks J.P.Sargent and K.H.G.Ashbee..... | 77 |
| Aramid/Epoxy vs. Graphite/Epoxy: Origin of the Difference in Strength at the Interface L.Penn, F.Bystry,W.Karp and S.Lee..... | 93 |
| Fracto-Emission from Fiber-Reinforced and Particulate Filled Composites J.T.Dickinson, A.Jahan-Latibari and L.C.Jensenn..... | 111 |
| Surface Treatment of Conductive Carbon Blacks and Their Effect on the Properties of Conductive Composites P.Datta and R.N.Friel..... | 133 |

| | |
|---|-----|
| Surface Modified Aluminum-Poly(vinyl acetate) Interaction in the Presence of Water K.E.Nietering and W.G.Miller..... | 145 |
| PART III. STRUCTURE OF COUPLING AGENTS AND INTERFACES | |
| Kinetics and Mechanism of Aqueous Hydrolysis and Condensation of Alkyltrialkoxysilanes E.R.Pohl and F.D.Osterholtz..... | 157 |
| Structure and Properties of Silane Primers for Adhesive Bonding of Metals F.J.Boerio, C.A.Gosselin, J.W.Williams, R.G.Dillingham and J.M.Burkstrand..... | 171 |
| The Effect of γ -APS Substrate Modification upon the Chemical Adhesion of Poly(amic acid-imide) Films D.J.Belton and A.Joshi..... | 187 |
| Silane Coupling Agents for Basalt Fiber Reinforced Polymer Composites R.V.Subramanian and K.H.Shu..... | 205 |
| PART IV. INFLUENCE ON THE MATRIX STRUCTURE | |
| Theoretical Estimation of the Possibility to Regulate the Viscoelastic Properties and Tensile Strengths of Filled Polymers by Changing the Size of Supermolecular Domains in the Interphase Layers of Polymer Binders Yu.S.Lipatov, N.I.Korzhuk and V.F.Babich..... | 237 |
| Polymer Composites of Poly(p-phenylene terephthalamide) and Nitrile Butadiene Rubber: Part I. Preparation and Properties M.Takayanagi and K.Goto..... | 247 |
| Polymer Composites of Poly(p-phenylene terephthalamide) and Nitrile Butadiene Rubber: Part II. Calculation of Anisotropic Moduli Based on Microfibrillar Lattice Model M.Takayanagi and K.Goto..... | 271 |
| Thermostimulated Creep Study of the Interface of Glass Bead-Reinforced Epoxy Composites J.P.Bayoux, C.Pillot, D.Chatain and C.Lacabanne..... | 287 |

| | |
|---|-----|
| Applications of Solid-State Magic Angle NMR Spectroscopy to Fiber Reinforced Composites A.M.Zaper, A.Cholli and J.L.Koenig..... | 299 |
| Acid-Base Interactions and Some Properties of Composites H.P.Schreiber and Y.Li..... | 313 |
| PART V. SURFACES OF REINFORCEMENTS | |
| Characterization of the Surface and the Interface of the Carbon Fiber A.Ishitani..... | 321 |
| Surface Chemistry and Bonding of Plasma-Aminated Polyaramid Filaments D.E.Allred, E.W.Merrill and D.K.Roylance..... | 333 |
| Spectrochemical Characterization of Chemically Modified Surfaces D.E.Leyden and D.E.Williams..... | 377 |
| Desorption of Water from Glass Fibers G.M.Nishioka and J.A.Schramke..... | 387 |
| Predicting Enthalpies of Interfacial Bonding of Polymers to Reinforcing Pigments F.M.Fowkes, D.C.McCarthy and D.O.Tischler..... | 401 |
| Wettability of Reinforcing Fibers H.W.Chang, R.P.Smith, S.K.Li and A.W.Newmann..... | 413 |
| ISS/SIMS Analysis of Graphite Fiber Surfaces and the Thermo-oxidative Stability of Graphite Fiber/PMR-15 Polyimide Composites D.A.Scola and B.L.Laube..... | 423 |
| Author Index..... | 445 |
| Subject Index..... | 447 |