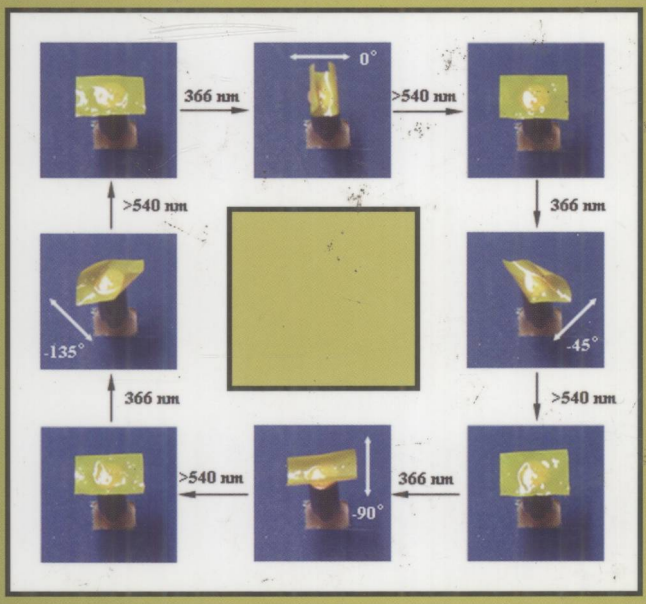
SMART LIGHT-RESPONSIVE MATERIALS

Azobenzene-Containing Polymers and Liquid Crystals



EDITED BY

Yue Zhao Tomiki Ikeda

WILEY

SMART LIGHT-RESPONSIVE MATERIALS

Azobenzene-Containing Polymers and Liquid Crystals

EDITED BY

Yue Zhao
University of Sherbrooke
Sherbrooke, Quebec, Canada

Tomiki Ikeda
Tokyo Institute of Technology
Tokyo, Japan

WILEY
A JOHN WILEY & SONS, INC., PUBLICATION

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

Library of Congress Cataloging-in-Publication Data:

Zhao, Yue, 1961-
Smart light-responsive materials : azobenzene-containing polymers and liquid crystals/Yue Zhao and Tomiki Ikeda.
p. cm.
Includes index.
ISBN 978-0-470-17578-1 (cloth)
1. Smart materials. 2. Polymers–Optical properties. 3. Azo compounds. 4. Liquid crystals. I. Ikeda, Tomiki. II. Title.
TA418.9.S62.Z53 2009
620.1'1295–dc22

2008035493

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

SMART LIGHT-RESPONSIVE MATERIALS

PREFACE

Azobenzene and its derivatives are fascinating molecules that display the reversible photoisomerization between the more stable trans and the less stable cis isomers. Although photoisomerization can result in important changes of properties for azobenzene molecules on their own, such as a large change in molecular shape and dipole moment, changes that can be imparted to polymers and liquid crystals when azobenzene is part of their structures or is associated with them are even more interesting. Indeed, reversible photoisomerization in azobenzene-containing polymers and liquid crystals enables the use of light as a powerful external stimulus to control or trigger the change of the properties of these two important classes of soft materials. For this reason, over the past two decades or so, there has been considerable worldwide research dedicated to azo–polymers and liquid crystals, ranging from fundamental studies to exploitation of applications. A number of important discoveries made in the 1990s have had a pivotal impact on this field. These include the surface relief grating that can readily be inscribed on azobenzene polymers using an interference pattern as a result of photoinduced mass transport and the isothermal photochemical liquid crystalline (LC)-to-isotropic (order-disorder) phase transitions because of the perturbation effect arising from the trans-cis photoisomerization. Today, the research field of azo-functional materials remains extremely active.

Although most research in the 1990s dealt mainly with the physical and optical properties of azo–polymers and liquid crystals important for optical information storage and switching, the field has witnessed important new developments and directions over the past 6 to 7 years. Amazing new phenomena continue to be discovered, such as the light-controllable bending of cross-linked LC azo–polymers, which, by showing how drastic the effect of azo–photoisomerization can have on a material, and offer new appealing opportunities. In recent years, there have been increasing efforts toward the development of diverse functional materials through rational molecular and materials designs that make use of established knowledge, and newer applications other than information storage and switching have emerged. Convinced that ongoing and future research on azobenzene-based light-enabled smart materials will have great potential and impact on both fundamental and applied

research, we think it is time to edit a book that, by reviewing recent developments and showing perspectives, provides a forum for discussion and exchange of new ideas. We would like to thank all the contributors for their great effort in helping us put together a book that should not only benefit researchers who work on azo–polymers and liquid crystals but should also be of interest to those who develop light-responsive materials without using azobenzene, as many of the discussed strategies and ideas about azobenzene could be adapted to other chromophores.

The vitality and sustained interest of this field can easily be noticed from the many research papers on azobenzene-based materials that continue to appear. Obviously, this book cannot cover all new, post-2000 developments. As editors, we have tried to ensure that all chapters are relevant to the theme of the book, with regard to research works that promise development of light-enabled smart materials based mainly on azo–polymers and liquid crystals. Despite the apparent diversity of the topics covered in this book, the cohesion of all chapters and the link between the different chapters are solid. Chapter 1 (Yager and Barrett) introduces basic azobenzene photochemistry, photophysics, and the wide variety of azo–materials. In Chapter 2 (Stumpe et al.), which reviews and discusses the photoinduced phenomena in supramolecular azo–materials, the basic background is set to help the general readership understand the fundamental aspects involved in and the ideas and interests behind the various types of smart azo–materials discussed in this book. This is followed by three chapters on photoinduced motion and the photomechanical effect of LC azo–polymers; (Chapter 3, Yu and Ikeda), amorphous azo–polymers (Chapter 4, Yager and Barrett), and colloidal particles (Chapter 5, Wang). The conversion of photo-energy into mechanical energy is certainly a major new direction in the field. In contrast to the colloidal particles self-assembled by amphiphilic random copolymers, micellar aggregates are the subjects of Chapter 6 (Zhao) and Chapter 7 (Tribet) and address the self-assembly of amphiphilic block copolymers and hydrophobically modified polymers, respectively. Solution self-assembled light-responsive micro- and nanostructures of azo–polymers and their potential applications as discussed in these chapters represent another exciting new research direction. Likewise, the research works presented in Chapter 8 (Seki) and Chapter 9 (Watanabe) explore azo–polymers in two dimensions and on surface. The next two chapters, Chapter 10 (Kurihara) and Chapter 11 (Zhao), mainly concern smart light-sensitive materials of small-molecule LCs. The last two chapters, Chapter 12 (Yu and Ikeda) and Chapter 13 (Liu and Brinker), provide excellent examples of new azo–materials and architectures, with a focus on azo-block copolymers in the solid state and azo-hydride silica materials, respectively.

Research on azobenzene-based smart materials is dynamically progressing. We hope this book gives a critical review of the new developments and shows new directions. However, what we want most for this book to accomplish is to generate interest among graduate students and young researchers in this exciting field and

help spark their imaginations with ideas for creative research. This is essential to ensure further research and development, and to help maintain the excitement in this field for many years to come.

YUE ZHAO
TOMIKI IKEDA

Sherbrooke, Quebec, Canada
Tokyo, Japan
January 2009

CONTRIBUTORS

PROFESSOR CHRISTOPHER J. BARRETT Department of Chemistry, McGill University, Montreal, Canada

PROFESSOR C. JEFFREY BRINKER Advanced Materials Laboratory, University of New Mexico and Sandia National Laboratories, Albuquerque, New Mexico

LEONID M. GOLDENBERG Fraunhofer Institute for Applied Polymer Research, Science Campus Golm, Potsdam, Germany

PROFESSOR TOMIKI IKEDA Chemical Resources Laboratory, Tokyo Institute of Technology, Yokohama, Japan

OLGA KULIKOVSKA Fraunhofer Institute for Applied Polymer Research, Science Campus Golm, Potsdam, Germany

PROFESSOR SEIJI KURIHARA Graduate School of Science and Technology, Kumamoto University, Kumamoto, Japan

DR. NANGUO LIU Specialty Chemicals Business, Dow Corning Corporation, Midland, Michigan

PROFESSOR TAKAHIRO SEKI Department of Molecular Design and Engineering, Graduate School of Engineering, Nagoya University, Chikusa, Nagoya, Japan

DR. JOACHIM STUMPE Fraunhofer Institute for Applied Polymer Research, Science Campus Golm, Potsdam, Germany

PROFESSOR CHRISTOPHE TRIBET Macromolecular Laboratory of Physics and Chemistry, University of Paris, Paris, France

PROFESSOR XIAOGONG WANG Department of Chemical Engineering, Tsinghua University, Beijing, China

DR. OSAMU WATANABE Toyota Central Research and Development Laboratories, Inc., Nagakute, Aichi, Japan

DR. KEVIN G. YAGER Polymers Division, National Institute of Standards and Technology, Gaithersburg, Maryland

PROFESSOR HAIFENG YU Department of Chemistry, Nagaoka University of Technology, Nagaoka, Japan

PROFESSOR YANLEI YU Department of Materials Science, Fudan University, Shanghai, China

YURIY ZAKREVSKYY Fraunhofer Institute for Applied Polymer Research, Science Campus Golm, Potsdam, Germany

PROFESSOR YUE ZHAO Polymer and Liquid Crystal Laboratory, Department of Chemistry, University of Sherbrooke, Québec, Canada

CONTENTS