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Advances in Polymer Science

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Polymers and Light

With contributions by
S. Georgiou · W. Kautek · J. Krüger · T. K. Lippert
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The series presents critical reviews of the present and future trends in polymer and biopolymer science including chemistry, physical chemistry, physics and material science. It is addressed to all scientists at universities and in industry who wish to keep abreast of advances in the topics covered.

As a rule, contributions are specially commissioned. The editors and publishers will, however, always be pleased to receive suggestions and supplementary information. Papers are accepted for "Advances in Polymer Science" in English.

In references *Advances in Polymer Science* is abbreviated *Adv Polym Sci* and is cited as a journal.

The electronic content of APS may be found at
<http://www.springerLink.com>

ISSN 0065-3195

ISBN 3-540-40471-6

DOI 10.1007/b12437

Springer-Verlag Berlin Heidelberg New York

Library of Congress Catalog Card Number 61642

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Printed in Germany

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Typesetting: Stürtz AG, Würzburg

Cover: Künkelopka GmbH, Heidelberg; design&production GmbH, Heidelberg

Printed on acid-free paper 02/3020/kk - 5 4 3 2 1 0

Volume Editor

Dr. Thomas K. Lippert

Paul Scherrer Institut
5232 Villigen-PSI
Switzerland
E-mail: thomas.lippert@psi.ch

Editorial Board

Prof. Akihiro Abe

Department of Industrial Chemistry
Tokyo Institute of Polytechnics
1583 Iiyama, Atsugi-shi 243-02, Japan
E-mail: aabe@chem.t-kougei.ac.jp

Prof. Ann-Christine Albertsson

Department of Polymer Technology
The Royal Institute of Technology
S-10044 Stockholm, Sweden
E-mail: aila@polymer.kth.se

Prof. Karel Dušek

Institute of Macromolecular Chemistry, Czech
Academy of Sciences of the Czech Republic
Heyrovský Sq. 2
16206 Prague 6, Czech Republic
E-mail: dusek@imc.cas.cz

Prof. Dr. W. H. de Jeu

FOM-Institute AMOLF
Kruislaan 407
1098 SJ Amsterdam, The Netherlands
E-mail: dejeu@amolf.nl

Prof. Jean-François Joanny

Institute Charles Sadron
6, rue Boussingault
F-67083 Strasbourg Cedex, France
E-mail: joanny@europe.u-strasbg.fr

Prof. Hans-Henning Kausch

c/o IGC I, Lab. of Polyelectrolytes
and Biomacromolecules
EPFL-Ecublens
CH-1015 Lausanne, Switzerland
E-mail: kausch.cully@bluewin.ch

Prof. S. Kobayashi

Department of Materials Chemistry
Graduate School of Engineering
Kyoto University
Kyoto 615-8510, Japan
E-mail: kobayasi@mat.polym.kyoto-u.ac.jp

Prof. Prof. Kwang-Sup Lee

Department of Polymer Science & Engineering
Hannam University
133 Ojung-Dong
Teajon 300-791, Korea
E-mail: kslee@mail.hannam.ac.kr

Prof. L. Leibler

Matière Molle et Chimie
Ecole Supérieure de Physique
et Chimie Industrielles (ESPCI)
10 rue Vauquelin
75231 Paris Cedex 05, France
E-mail: ludwik.leibler@espci.fr

Prof. Timothy E. Long

Department of Chemistry and Research Institute
Virginia Tech
2110 Hahn Hall (0344)
Blacksburg, VA 24061, USA
E-mail: telong@vt.edu

Prof. Ian Manners

Department of Chemistry
University of Toronto
80 St. George St.
M5S 3H6 Ontario, Canada
E-mail: imanners@chem.utoronto.ca

Prof. Dr. Martin Möller

Deutsches Wollforschungsinstitut
an der RWTH Aachen e.V.
Veltmanplatz 8
52062 Aachen, Germany
E-mail: moeller@dwi.rwth-aachen.de

Prof. Oskar Nuyken

Lehrstuhl für Makromolekulare Stoffe
TU München
Lichtenbergstr. 4
85747 Garching, Germany
E-mail: oskar.nuyken@ch.tum.de

Prof. Brigitte Voit

Institut für Polymerforschung Dresden
Hohe Straße 6
01069 Dresden, Germany
E-mail: voit@ipfdd.de

Prof. Gerhard Wegner

Max-Planck-Institut für Polymerforschung
Ackermannweg 10
Postfach 3148
55128 Mainz, Germany
E-mail: wegner@mpip-mainz.mpg.de

Preface

This special volume *Polymers and Light* deals with very recent developments of photon interactions with polymers, in areas outside the scope of the familiar photoresist technique and optical lithography. Recent developments in microlithography still apply the same processing steps (irradiation of the photoresist through a mask followed by a subsequent 'wet' chemical development step), but with new photoresist materials, and new irradiation sources, i.e. excimer lasers that emit in the UV, e.g. at 157, 193, and 248 nm. Excimer lasers are now the main photon sources for microlithography in many research laboratories and in industry.

This successful story started in 1977 when the first excimer laser became commercially available (Lambda Physik), which was only 7 years after the development of the first excimer (1970 by Basov et al.). In their first years, these lasers were used as unique, powerful photon sources for photochemical experiments. The first reports involving excimer laser induced structuring of polymers, were published in 1982, nearly simultaneously by Srinivasan et al. and Kawamura et al.. Excimer laser irradiation allowed high resolution structuring of polymers without any additional development steps, acting as a true dry etching technique, which was envisioned as a replacement or alternative technique to classical lithography with resists. In the following years, many problems were encountered for this application, such as low sensitivity of the polymers, contamination of optics and surface with the ablation products (debris), and chemical modification of the polymers which continuously changed the processing parameter. Nevertheless, there has been renewed interest in polymer ablation as a result of special niche applications found in an area that may be described as *microstructuring*. Examples of these applications include the via-hole drilling on multi-chip modules at IBM, or the drilling of the inkjet printer nozzles. Photon induced direct structuring of polymers has recently attracted more attention due to new applications, new instruments (photon sources), and new material developments. These new methods for polymer processing have the potential to create novel applications for polymers, and reveal the opportunity for polymer chemists to perform unique research at the interface of polymers and lasers. The utilization of high laser energies can result in truly new processes which are not possible to achieve with the classical low energy irradiation.

S. Georgiou summarizes the recent successes of laser cleaning of polymer substrates. The basic principles of the three most important cleaning processes, i.e. layer-by-layer removal, selective removal of impurities, and particle removal, are discussed in detail. Particular emphasis is given to the possible side effects of these procedures, which will determine the further success of these methods. Various experiments aimed at a better understanding of these processes using model or polymer systems are presented. Examples of its potential, especially to paintings, are shown together with the capabilities of various on-line monitoring tools.

The contribution of T. Lippert describes a different approach to polymer ablation, discussing the development of polymers that are designed for laser ablation at a specific wavelength (308 nm). These special polymers reveal properties that show the possibility of overcoming most problems associated with ablation of polymers: these polymers reveal a high sensitivity, show no-surface modification, and yield mainly gaseous products. These polymers are also used as probes for the mechanisms of polymer ablation that are still under discussion (photochemical vs. photothermal). Various experimental data on the designed polymers and a comparison with a reference polymer (polyimide) suggest the importance of a photochemical mechanism in the ablation process.

Two recent exciting developments in ablation are discussed by Krüger/Kautek and Zhang: the application of ultrashort pulses and the utilization of synchrotron radiation (x-rays).

These two contributions are the first reviews which summarize the recent results of ultrafast and x-ray structuring of polymers.

Femtosecond laser irradiation of polymers allows direct structuring of polymers that are transparent at most laser wavelengths (e.g. Teflon), and reveal structures with high quality and a very small heat affected zone (HAZ). Similarities and differences between the ablation of polymers and dielectrics are shown, together with the influence of the pulse duration and band-gap of the materials. Various potential applications in medicine and biosensoric are discussed.

Synchrotron structuring of polymers, using a 'small' synchrotron ring with 10 m circumference can be applied for directly structuring polymers with the high aspect ratios that are very difficult to obtain by other methods, e.g. laser irradiation. The fundamentals of X-ray lithography are discussed, followed by a comparison of synchrotron structuring with laser ablation and X-ray lithography (e.g. LIGA). The mechanism is different from laser ablation and an example of its potential application is also shown.

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