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Polymers and Light

With contributions by
S. Georgiou · W. Kautek · J. Krüger · T. K. Lippert
Y. Zhang

Springer

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.

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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 multichip 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.

Villigen, January 2004 Thomas K. Lippert

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