

## Preface

Soon after the discovery of polymeric materials it became evident that they were quite sensitive to radiation of all kinds. Chemical and structural degradation was observed first after illumination with light and UV irradiation, and later with  $\gamma$ -rays and energetic charged particles such as electrons and ions. In the course of these examinations it was realized that polymer irradiation is not necessarily detrimental, but that it might even be good for technological applications of some kind or other. This increased the interest of researchers who initiated systematic studies in this field. Quite a number of radiochemists have devoted themselves since the 1950s and 1960s to the examination of radiochemical processes in polymers after  $\gamma$ -ray and electron irradiation.

As, on the other hand, ion accelerators were at that time still practically exclusively the domain of nuclear physicists, there existed hardly any systematic studies on ion-irradiation effects in polymers. This changed only when modern electronics emerged. When doping of semiconductors via ion implantation masks of polymers – so-called photoresists – became common to obtain finely structured devices, the need for understanding these photoresists became obvious, concerning both their chemistry and their structural changes upon energetic ion impact. Taking into account the tremendous economical impact of this new development on our modern society, this turned out to be the real starting point of common interest in ion–polymer interactions. Meanwhile, ion irradiation of polymers has become a rapidly expanding field.

Parallel to the above-described development of low-energy ion irradiation of polymers (with typically 20 to 500 keV ion beams), the discovery of tracks of more energetic ions (with energies in the MeV to GeV range) in insulators and their enhanced etchability had a major impact on the field of ion–polymer interaction. Though the first tracks were recorded in inorganic crystalline materials such as mica and  $\text{MoS}_2$ , it soon became apparent that some very common polymers such as polycarbonate, polyacetate, cellulose nitrate, etc., could be applied even better for track production due to their greater homogeneity, size, purity, flexibility and cheaper availability than the natural materials. This discovery gave birth to an explosive development in dosimetry for a wide range of applications, e.g., in medicine and biology, geology, mineralogy, oil and uranium prospecting, space research and other disciplines. In all these cases, the ion tracks recorded in suitable polymer foils

are used as evidence for the impact of the corresponding energetic particles, i.e., the polymers serve as ion detectors.

With the possibility to produce well-defined parallel pores in polymer foils by ion irradiation and subsequent etching, the way for further applications arose. Companies were founded that nowadays offer a wide range of porous polymer foils with different parameters. They are essentially applied as high-quality filters, e.g., in purification of chemicals for the pharmaceutical and electronic industries. Other possible applications, e.g., as platforms for biomedical experiments, or as templates for metallic and ceramic replicas, are at present still poorly elaborated. One should note the recent promising development in optoelectronics where highly transparent ion-irradiated polymers are used for the construction of waveguides and other optical devices, by suitably modifying the optical refractive index via ion irradiation. In a similar way, the tailoring of other polymer properties such as their conductivity, biocompatibility, elasticity, hardness, etc., by ion irradiation may still lead to other useful applications in the near future. We also should not forget to mention the dramatic development in plasma technology, where ions of lowest energies (some eV to keV) are used for surface modification of materials, including polymers. This field will, however, not be treated in this book as there already exist good overviews.

It appears that the field of ion-polymer interaction will soon undergo a new challenge. With the competition of semiconductor electronics towards smaller and smaller dimensions soon reaching a critical state due to the prohibitively increasing cost of further miniaturization, many of the smaller companies started looking for alternative ways of development, in order not to collapse financially. Polymeric electronics is one of the most promising alternative fields, due to the possibility to produce flexible large-area panels for monitoring or sensing, and due to its simplicity and low cost of production, as compared to the highly sophisticated and expensive semiconductor micro- and nanoelectronics. It has been shown in recent years that all-polymeric electronic devices can be produced by classical low-tech recipes as simple as painting and printing! Now, as the way is paved towards the use of polymers as active electronic base materials, one may expect that tailoring of the future polymeric devices by ion beams will also gain importance, either via conventional lithographic-mask techniques or with microbeams, or even by using ion-beam-produced microporous foils as a carrier medium for electronic devices. We therefore envisage that one might soon be able to produce a range of advanced but still cheap polymeric products for future electronic, electrical, mechanical and optical devices.

In conclusion, ion irradiation of polymers has become a wide field. We present here for the first time low- and high-energy ion irradiations of polymers in the same book, in order to highlight their common base as well as their differences. The basic physical and chemical mechanisms of ion-polymer interactions have been established so that today we have reached at least some general understanding of the processes occurring. However, there are still

astonishingly large gaps in the knowledge of closer details that makes further research in this field absolutely necessary. It is seen as one task of this book to point clearly to the still open questions in order to encourage the reader to help clarify them.

Due to the large size of this field, the contents of the book on ion–polymer interactions is split into two volumes. The first one treats the basic physico-chemical ion–polymer interaction mechanisms, and the second one deals with transport processes in ion-irradiated polymers, and with their applications. Of course, the description of ion-irradiation of polymers requires a basic understanding of both the polymers and the irradiation process themselves, which is therefore included in the first volume. Furthermore, this volume contains a chapter summarizing the – partly less common – analytic techniques that allowed one to obtain the present understanding of the irradiation processes.

Applications of ion-irradiated polymers usually require some additional preparatory manipulations such as their etching or the selective incorporation of dopants. Therefore the second volume begins with a chapter on the transport of matter in such materials, and its consequences. Subsequently the applications are treated. Here, not only are the presently well-established applications described, but also those that we feel will emerge in the near future. We try to give the reader strategies to accomplish this goal.

Clearly, this book can only describe an intermediate stage of a rapidly developing field at the beginning of the third millenium, and therefore it can give only a transient overview about the present state-of-the-art and to point to the emerging trends. I hope that this aim was achieved.

Thanks are due to everybody who contributed to this book directly or indirectly by numerous discussions at conferences, meetings, etc. Apart from giving special credit to all the coauthors of this book, I want to acknowledge thankfully the continuous interest and help of Prof. Lewis T. Chadderton, Dr Manfred Müller, and Dr Jiri Vacík over the many years during which the idea of this book emerged, and that helped clarify many findings that appeared to be a riddle at the moment of their discovery. We are also obliged to Dr Ricarda Klett, Dr Arne Schmoldt, Prof. Kamal K. Dvivedi, Dr Svarnali Ghosh, Mr Prashant Alegaonkar and Mr Alexander Petrov who obtained quite a number of the results compiled in this book, partly in the framework of their PhD or postdoctorate studies. Many other important personal communications are mentioned in the references. We thank to Prof. Pedro Grande for his kind help in the chapter on stopping powers and ranges, to Prof. Jochen P. Biersack and to Dr. Amita Chandra for their critical reading, and to Dr. Mahalakshmi Iyer for her technical help in the last chapter of this book. Thanks also to the coauthors for their help in the chapters in which they are not named. Thanks also to all Publishing Companies who allowed the reproduction of figures in this book.

We are also obliged to the organizations that enabled this work by giving us financial support, especially to the DAAD and CAPES in the framework of

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the German–Brazil agreement “POBRAL”. I also must not forget to mention the continuous support by my home institute, the Hahn-Meitner-Institute, Berlin. Last but not least I want to thank my good friends all over the world – especially to the families Chadderton, Stange-Ferreira, and Berdinsky, and also to my own family who always supported me with constant encouragement, friendship and love, and thus cared for the warm and good atmosphere necessary to write this book.

Berlin, February 2004

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<http://www.springer.com/978-3-540-04027-9>

Fundamentals of Ion-Irradiated Polymers

Fink, D. (Ed.)

2004, XV, 406 p., Hardcover

ISBN: 978-3-540-04027-9