Preface

During the past 50 years ion beam technologies have been proven to be powerful tools in the continuously growing field of materials science. Ion beams are used for tailoring the physical and chemical properties of thin films, surfaces and interfaces. Nanostructures can be formed or modified and nanocomposite materials can be synthesised with new properties which do not exist in natural materials. In the past two decades very high-energy ion beams from accelerators usually used for nuclear and particle research became available with the parameters making them suitable for materials science. This stimulated intensive research and the use of so-called swift heavy ions in ion-beam based materials science received much attention. This was an important step to fulfil the demand for modifying more thick or buried layers. Moreover, the research in materials science with swift heavy ions induced new applications as for instance the controlled shaping of embedded nanoparticles, which could not be imagined beforehand. Besides its use in various device technologies, ion beams play an important role in a number of other fields. Examples for that are materials research and treatment of radioactive waste in nuclear fission and fusion technologies, optimization of prosthetic components and the use of ion beams in cancer treatment. Additionally, ion-beam based analytical techniques are very important not only in materials science but also in environmental studies and in the field of preservation of cultural heritage.

Ion irradiation of solids has two main effects: the introduction of foreign atoms and the energy deposition into the material. The specific application of ion beams requires a thorough knowledge of the interactions of the energetic ions with the corresponding material. These interactions determine the depth at which the ions come to rest and cause structural modifications in the material (radiation damage). The radiation damage measured after ion irradiation depends on the primary energy deposition of the ions and the external irradiation conditions and is characteristic for a given material. In some cases radiation damage results in useful changes of materials properties but typically the damage has to be reduced or removed by subsequent annealing processes in order to achieve the desired results. The choice of suitable methods for damage annealing often strongly depends on the kind and concentration of damage produced during ion irradiation in the respective material. Consequently, the investigation of ion-beam induced damage formation is an indispensable part in the field of ion beam physics.

The fundamentals of ion–solid interaction, ion-beam induced damage formation in a broad variety of materials and theoretical description of damage formation have been subject of intensive studies of a large number of research groups around the world. This resulted in an enormous and still growing number of scientific papers. Various excellent monographs about ion beam physics appeared in recent years. Apart from the numerous scientific papers and monographs on the one hand and pure textbooks on the other, a comprehensive description of the theory of ion stopping in matter, a summary of models and the concepts that have been developed over time for characterisation of damage evolution as well as an overview of the state-of-the-art knowledge on damage formation in various classes of materials is still missing. With the present book we aim at filling this gap.

The book is organised in four parts. Part I provides the physical basics of ion–solid interaction. This includes a complete treatment of the theory of ion stopping in materials, i.e. the treatment of nuclear and electronic energy loss processes. Two further chapters give an overview about existing models for the description of damage formation due to electronic and nuclear interaction, respectively. If possible the general concepts are compared to each other and illustrated with real examples. The last chapter of this part is devoted to the physical basics of ion-beam induced synthesis of nanostructures. Part II deals with damage formation, amorphization and (re)crystallisation of semiconductors and ceramics, i.e. of covalent-ionic materials, due to nuclear energy deposition. The effect of high electronic energy deposition in solids is the topic of Part III. Structural modifications and phase transformations in crystalline insulators, metals and semiconductors are summarised. Additionally one chapter of this part reports on effects of electronic energy deposition in amorphous semiconductors. The final part, Part IV, presents selected applications of ion beams. Here the focus is on shaping and modification of nanoparticles and nanostructures and on the use of ion-beam induced effects for modification of optical materials.

It should be mentioned that not all existing literature could be taken into consideration in detail, but the contents of the various chapters are initially based on scientific results of the authors and their groups. Additional references to works of other authors are integrated. Besides well-established experimental results also possible limitations in their interpretation and open problems are addressed. In this respect the book should be suitable as material for special courses for graduate, postgraduate and Ph.D. students. Additionally it can be used as a source of information for researchers who are interested in this field.

Finally we feel the need to thank all co-authors who participated in the project with their valuable and highly interesting contributions. With extreme sadness we had to take note of the early death of our colleague, Mark C. Ridgeway, who significantly contributed not only to this book but to the field of ion beam physics in general. We shall always honour his memory.

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