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Swift Heavy Ions for Materials Engineering and Nanostructuring

D.K. Avasthi
G.K. Mehta
Inter University Accelerator Centre
New Delhi
India

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Preface

Ion beams have been of increasing focus in fundamental and applied research in materials science. Development of ion beam facilities along with sophisticated devices for the characterization and analysis on nano scale has given a new direction in nanotechnology and towards tailoring desired properties in materials for their applications in various fields. A large amount of interesting research work in the direction of engineering materials properties with high energy heavy ion beams has been performed. Need was felt to have an overview of the work done in this direction by using high energy heavy ions [Swift Heavy Ions (SHI)].

The prime purpose of the book is to bring out salient features of research in materials with swift heavy ions. It will be of interest to young scholars engaged in research with swift heavy ions to focus towards specific problems in this emerging area. It has evolved from the experience gained by interacting with the large community of young researchers from various universities and research institutions in India and abroad. It was felt that because it is a relatively new area of research which is providing avenues of exploration in various directions, there is possibility of missing the directions required to focus on the emerging challenges in various areas, and that request from them for their contribution for this book may help in focussing their attention towards focussed goals. A consolidated compilation of contributions from the users of the high energy heavy ions for materials studies is being attempted here.

Swift heavy ions have a unique feature of depositing a large energy density in materials which can drive the material far from equilibrium, resulting in modifications in materials, difficult to achieve by other means. Studies on understanding of the modifications produced by swift heavy ions give an insight to the interaction of energetic ions with materials. The irradiation of materials by swift heavy ions can result in different effects in materials such as defect annealing, defect creation, ion track formation, plastic deformation etc. and these can be tuned by ion beam parameters. High energy density provided by SHI in laboratory allows to simulate extreme conditions.

Ion beams have been used for a long time to characterize the materials with techniques developed specifically for the situations which could not be handled with the conventional techniques. The worry that the ion beams being used to characterize the samples will damage the material soon turned into a challenge that the modifications in the properties during irradiation can be monitored in dynamic mode which can provide possibility of controlled change in the properties of the materials. This started the discipline of "Materials Engineering with Ion Beams". It has now emerged as an area with immense scope of development particularly because of the way it is becoming possible to create ion beams with specific and diverse characteristics giving rise to new avenues to exploit. Considering the fact that the low energy ions have been in the field for a long time it was decided to concentrate on the high energy heavy ions.

This book is an effort to present a scenario of research in materials science with SHI in a way which could be useful for the students planning research in ion accelerator based materials science. We would like to emphasize that the material is prepared with the help of researchers in this area and is based on their publications and existing materials. The challenge was to try and convert the large number of research publications in the field into a kind of a text to motivate the students to plan their experiments with a focus on engineering some well defined property of some materials to make its application possible.

First three chapters provide an overview of the field, challenges in materials and state-of-the-art developments in ion beams, very brief description of ion matter interaction and survey of the wide field of applications of ion beams for the characterization and analysis of materials. The next two chapters are on the SHI induced ion beam mixing and SHI for synthesis and modification of nanostructured materials. The last chapter focusses on engineering the properties of materials with SHI, where various types of materials are considered. It covers different types of materials. It has not been possible to cover all the materials which have been worked upon using SHI irradiation.

This exposition of experimental work owes much to the persons who provided the information about the importance of ion beam interaction in changing the properties of materials in unique ways. We had significant inputs from the present and past research scholars who had been at IUAC for their PhD. We gratefully acknowledge Amit Kumar (now at LPMS, Toulouse, France), Y.K. Mishra (now at Kiel University, Germany), S.K. Srivastava (now faculty in IIT Kharagpur), S. Ghosh and Rajendra Singh (now faculty in IIT Delhi), D.C. Agarwal, R. Singhal and Yogita Batra. There are many to acknowledge but special role was played by Drs Naresh C. Mishra, Ajay Gupta, K.M. Varier, Anand Pathak, R.G. Sharma, Ashok Kumar, A.C. Chaudury, Ratnamala Chatterjee, S. Dhamodaran, Avinash Pandey, Utpal Joshi, T. Som, D. Behera, D. Mohanta and Maulik Patel, to name a few. The manuscript could only be completed because of the support from the colleagues in the Nuclear Science Centre [now Inter University Accelerator Centre—IUAC] who have

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February 2011

D.K. Avasthi
G.K. Mehta

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