

Series Editors' Preface

The Indian Institute of Metals Series is an institutional partnership series focusing on metallurgy and materials sciences.

About the Indian Institute of Metals

The Indian Institute of Metals (IIM) is a premier professional body (since 1947) representing an eminent and dynamic group of metallurgists and materials scientists from R&D institutions, academia and industry mostly from India. It is a registered professional institute with the primary objective of promoting and advancing the study and practice of the science and technology of metals, alloys and novel materials. The institute is actively engaged in promoting academia–research and institute–industry interactions.

Genesis and History of the Series

The study of metallurgy and materials science is vital for developing advanced materials for diverse applications. In the last decade, the progress in this field has been rapid and extensive, giving us a new array of materials, with a wide range of applications and a variety of possibilities for processing and characterizing the materials. In order to make this growing volume of knowledge available, an initiative to publish a series of books in metallurgy and materials science was taken during the Diamond Jubilee year of the Indian Institute of Metals (IIM) in the year 2006. IIM entered into a partnership with Universities Press, Hyderabad, and as part of the IIM book series, 11 books were published, and a number of these have been co-published by CRC Press, USA. The books were authored by eminent professionals in academia, industry and R&D with outstanding background in their respective domains, thus generating unique resources of validated expertise of interest in metallurgy. The international character of the authors' and editors has enabled the books to command national and global readership. This book series includes different categories of publications: textbooks to satisfy the requirements

of undergraduates and beginners in the field, monographs on select topics by experts in the field and proceedings of select international conferences organized by IIM after mandatory peer review. An eminent panel of international and national experts constitute the advisory body in overseeing the selection of topics, important areas to be covered, in the books and the selection of contributing authors.

Current Series Information

To increase the readership and to ensure wide dissemination among global readers, this new chapter of the series has been initiated with Springer. The goal is to continue publishing high-value content on metallurgy and materials science, focusing on current trends and applications. Readers interested in writing for the series may contact the undersigned series editor or the Springer publishing editor, Swati Meherishi.

About This Book

This book has two volumes, one on “Biomaterials for Musculoskeletal regeneration: Concepts” by Prof. B. Basu and another on “Biomaterials for Musculoskeletal Regeneration: Applications” by Prof. B. Basu and Prof. S. Ghosh. The volume on “Biomaterials for Musculoskeletal regeneration: Concepts” has comprehensive coverage on biological and material concepts in bone tissue engineering. It comprises of 12 chapters covering the basics of biological sciences relevant to biocompatibility; an overview of biomaterials and concepts of bone tissue engineering; desired mechanical properties of biomaterials and osteogenic tissues; aspects of ceramic processing; scope of additive manufacturing; concepts of fracture toughness; toughening mechanisms, friction and wear behaviour; fundamental aspects of experimental techniques to evaluate degradation, toxicity, and *in vivo* biocompatibility of biomaterials; properties of 3D porous scaffolds and simulator studies; new design concepts for developing multifunctional biomaterial; and newer approaches for enhancement of biocompatibility properties. The next volume on “Biomaterials for Musculoskeletal Regeneration: Applications” jointly authored by Prof. B. Basu and Prof. S. Ghosh provides important features demonstrating the opportunity of biomaterial development using various conventional and advanced fabrication techniques, prototype development and clinical trials. This book comprises of 12 chapters with 10 chapters exclusively presenting case studies of illustrative examples of biomaterials development. Toughness enhancement of hydroxyapatite-based bioceramic implants without compromising on cytocompatibility; new design concepts and newer approaches for the development of multifunctional biomaterials and with multiscale porosity; osteointegration and implant stability of strontium-containing glass ceramics; injection moulding route; and 3D print cartilage-based prototype development are all described in detail. As a whole, this textbook with both volumes is providing a new horizon for the readers to develop the basic and advanced understanding of the bone tissue engineering, and

applications, without any inhibitions of a non-biology background. The author and the editors are of conviction that this book will motivate students and researchers to develop new bioengineering strategies that trigger novel biomaterial development. We wish all readers enrichment in knowledge and motivation. Also, we await the feedback for improving the book when it goes to the second edition.

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Preface

The impact of the field of biomaterials for musculoskeletal regeneration has been truly reflected in high impact publications in leading science journals and research funding for large interdisciplinary research programs around the world. A common thread of motivation for such intense research activities globally has been the immense potential of the biomaterials in treating various musculoskeletal diseases. For example, the bone/joint degenerative and inflammatory problems affect millions of people worldwide. Because of the growing geriatric population, these problems account for half of all chronic diseases in people over 50 years of age. Osteoporosis is another prevalent bone disorder, being one of the most common health problems in the middle aged populations and post-menopausal women, worldwide. The prosthetic infection has been another cause for revision surgery in many patients undergoing orthopedic surgeries. A number of chapters in this book will discuss the case studies related to some of these human diseases.

The ultimate impact on human healthcare has attracted a large number of materials engineers (more than other engineering disciplines) to pursue research on biomaterials over the last few decades around the world. In fact, many materials science and engineering departments in those universities offer the compulsory course on this subject at undergraduate and graduate levels. Different books treat this subject in different manners. The sustained progress in this field demands a textbook highlighting some of the major applications of the biomaterials for musculoskeletal applications. One of the authors, Dr. Bikramjit Basu, being a metallurgist by formal undergraduate and postgraduate training and a ceramicist by virtue of doctoral training, and the other author, Dr. Sourabh Ghosh with a background of textile technology and surgical oncology, together have conceptualized this book in a different manner than the existing books on this subject. In particular, this book has the following important features: (a) coverage of the various conventional and advanced manufacturing of materials as well as mechanical and biocompatibility properties of newly developed biomaterials through a number of case studies demonstrating the opportunity of biomaterial development and (b) a discussion on how to take lab scale research to a patient's bedside through technology readiness level assessment of biomedical device prototype development and

clinical trials with examples. In view of such important features, this book will be extremely useful for the non-specialist and the beginners in the field of biomaterials.

It is expected that this text book will help the young researchers to appreciate the fact that one does not need to know the entire spectrum of biological sciences to conduct cutting edge research on biomaterials.

This text book entitled “*Biomaterials for Musculoskeletal Regeneration: Application*” contains altogether 12 chapters with 10 chapters on case studies illustrative examples of biomaterials development. The introductory chapter emphasizes the clinical perspective of this field and this is followed by several case studies, essentially illustrating various aspects of development of biomaterials for different biomedical applications. In the first of such chapters, the biocompatibility, cell adhesion and proliferation of hydroxyapatite–titanium (HA-Ti) bulk nanocomposites are presented. The toughness enhancement of bioceramic implants, particularly for hydroxyapatite-based materials, has been a major concern. This aspect has been discussed in reference to the HA-Ti-based composites with moderately high fracture toughness properties. The results of *in vitro* studies are also summarized to demonstrate that cytocompatibility is not compromised while achieving better toughness properties. This is followed by a chapter on micro- and macroporous scaffolds, primarily based on HA. Some of the new design concepts in developing implants and the perspective of the development of multifunctional biomaterials with multiscale porosity are emphasized. This chapter closes with the brief discussion on some of the newer approaches for the enhancement of biocompatibility properties.

The following chapters thereafter discuss strontium-containing glass ceramics and mica glass ceramic (Chap. 5). The results of both in short-term and long-term osseointegration together and implant stability are majorly discussed in Chap. 4, and to this end, the results of histology and microcomputer tomography are summarized. The possibility of developing some fascinating microstructures and composition-dependent *in vitro* properties are discussed in Chap. 5. The next chapter, i.e. Chapter 6, presents the case study on HDPE-based hybrid composites using injection moulding route, and their biocompatibility properties are also summarized. One important aspect is the biomaterial-based prototype development. This aspect is discussed in Chap. 7 in reference to HDPE hybrid composite-based acetabular socket development for total hip surgery. In Chap. 8, strategies and unsolved challenges to develop printed cartilage has been addressed.

The clinical trials are important aspect in translational research on biomaterials. The basic premise as well as a thorough discussion on randomized control trials is provided in Chap. 9. This is followed by a chapter on clinical trials for biomaterial constructs for maxillofacial reconstruction (Chap. 10). The technology and manufacturing readiness level to take laboratory-scale research to prototype development is discussed in Chap. 11. The last chapter provided author’s perspective on the present status and future growth of this societally important field of research. In summary, the various chapters globally present the authors’ perspective on various stages to be followed while developing a new biomaterial—from materials processing to physical properties/mechanical properties measurement and to *in vitro/in vivo*

biocompatibility assessment. Such an integrated approach requires one to acquire a healthy theoretical foundation of both materials science and biological sciences, and these aspects are broadly discussed in a large number of chapters in this book.

This book is an outcome of several years of teaching undergraduate- and postgraduate-level courses in the area of biomaterials, being offered to students of Indian Institute of Technology Kanpur, Indian Institute of Technology Delhi, and Indian Institute of Science, Bangalore, India. Several chapters of this will also reflect on the extensive research from the author's research group, both at IIT Kanpur and at IISc, Bangalore, as well as IIT Delhi in last one decade, which is being supported by Council of Scientific and Industrial Research (CSIR), Department of Biotechnology (DBT), Department of Science and Technology (DST), Indo-US Science and Technology Forum (IUSSTF), and UK-India Education and Research Initiative (UKIERI).

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