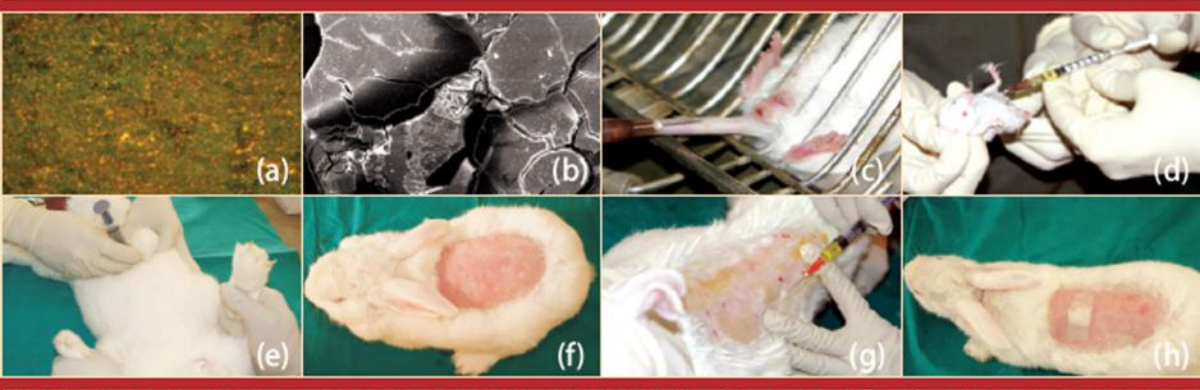
BIOACTIVE GLASSES *for* IMPLANT APPLICATIONS

V RAJENDRAN & SK BHANDARI



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BIOACTIVE GLASSES FOR IMPLANT APPLICATIONS

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BIOACTIVE GLASSES FOR IMPLANT APPLICATIONS

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Figures on the cover: (a) Epifluorescence micrograph of NBG-modified titanium surface after exposure in simulated body fluid (SBF); (b) SEM image of P_2O_5 (47 %)-CaO (30.5 %)-Na_2O (22.5 %)-K_2O (0 %)- immersion in SBF for 10 days; (c&d) Study of leachables present in/on the material under consideration; (e) General anesthesia using intra-peritoneal injection of thiopentone sodium; (f) Part preparation to assess the localised reaction of tissue to leachables and delayed contact dermatitis; (g) Study to assess the localised reaction of tissue to leachables present in/on the material under consideration; and (h) Study of potential to induce delayed contact dermatitis (type IV dermatitis) attributed to endogenous/extraneous substance present in the material under consideration.

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Preface

Biomaterials is an evolving field that facilitates to make devices and implants to replace diseased, damaged, missing, or lost tissue structures in the body. Biomaterials find wide spectra of applications in medicine in areas like orthopaedics, dentistry, and reconstructive surgery, etc., for augmentation or replacement of natural tissues. Over a period of time better understanding in the fields of medicine and biomaterials led to development of new generation of biomaterials with enhanced properties like strength, stiffness, fatigue, design, bioactivity, and biocompatibility. In view of the above factors, biomaterials have come up with different characteristic properties namely bioinert materials (first-generation biomaterials), bioactive and bioresorbable materials (second-generation biomaterials), and materials designed to stimulate specific cellular responses at the molecular level (third-generation biomaterials). Although, the first-generation biomaterials provide a relief from sufferings for thousands of patients through an existing procedures for bone and joint replacement, etc., but has a time limitation. The advent of second-generation biomaterials with key features, namely, bioactive and bioresorbable properties extends the human lifetime. The bioactive materials such as bioactive glasses and glass ceramics, ceramics, and composites are widely used in orthopaedic and dental applications. Generally, bioactive glasses and glass ceramics play an important role in various surgical specialities including dentistry. However, the third-generation biomaterials are one of the newer materials with combination of both resorbable and bioactive characteristics will help to repair their own tissue by stimulating specific cellular responses.

With these considerations, this monograph is intended to provide an overview of the principle, development, and practice of bioactive glasses for biomedical applications. The monograph is composed of five chapters. In the first chapter, an introduction to biomaterials and bioactive glasses based on their physiochemical and mechanical properties is given along with review of the work. The structure and properties of biomaterials are discussed in brief which are used to optimise the bioactive glasses and glass ceramics for better bioactivity and biocompatibility in the chapter second. Similarly, in chapter three, the various methods used for the synthesis of bioactive glasses, and characterisation techniques along with optimisation studies are discussed. In chapter four, the different applications of bioactive glasses and glass ceramics are given with practical illustrative applications.

We are thankful to Director, Defence Scientific Information and Documentation Centre (DESIDOC), Delhi, for sanctioning this monograph project and extending all the necessary support and guidance throughout the tenure of the project for the successful

completion of the monograph. We thank Dr W Selvamurthy, DS & CC R&D, Life Sciences, DRDO for writing Foreword for this monograph.

It is our privilege to acknowledge Lion. Dr KS Rangasamy M.J.F., Chairman and Shri R Srinivasan, Secretary, KSR Group of Institutions and Dr K Thyagarajah, Principal, KS Rangasamy College of Technology for their constant support, encouragement and also providing congenial atmosphere to complete this monograph.

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We are very thankful to the research team comprising Dr A Nishara Begum, Dr G Rajkumar, Shri Aravindan, Ms AV Gayathri Devi, and Shri B Saravanakumar for providing facilities to carry out the research work under bioactive glasses and nano bioactive glasses in the author's laboratory. We acknowledge the support given by scholars Shri P Manivasakan, Shri M Rajkumar, Shri R Yuvakkumar, Ms K Sasipriya, Shri K Sakthipandi, Ms S Sudha and Ms S Pavithra to compile the manuscript. We are thankful to Shri P Paramasivam, Ms M Gayathri and Ms S Karthika for their assistance in typesetting the monograph.

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Col (Dr) SK Bhandari

Chapter 1

Biomaterials

1.1 INTRODUCTION

Biomaterials are one of the advanced materials used for different biomedical applications. Biomaterials are being successfully used to repair or replace the damaged or diseased body parts in the human/animal body which in turn helps to improve the quality and span of the human life. Even though the clinical applications of biomaterials were started in early 1759, the importance of biomaterials for aseptic surgical technique was realised only during 1860s. The materials with different properties and characteristic behaviours are used for different biomedical applications such as surgical sutures and needles, catheters, orthopaedic hip replacements, vascular grafts, implantable pumps, cardiac pacemakers, etc. Novel materials like nuclear, magnetic, shape memory alloys, composites, etc., are developed with varied physico-chemical properties to meet the industrial requirements. The materials development has crossed almost three generations considering industrial requirements. Particularly, the recent developments in the field of medicine, surgical instruments and implants for both prosthetic and orthopaedic applications are ever increasing in our day to day life.

Earlier, materials such as stainless steel, *Co-Cr-Mo* alloy, and *Ti* and its alloys have been widely used as bone repairing material due to their superior mechanical strength, high corrosion resistance, and good biocompatibility. These materials are fixed to bone by mechanical interlocking and do not form any chemical bond with the living bone. Later, the above metals were coated with bioactive glasses and ceramics, to make them bioactive with natural bone, since the implants will get loosen over a long period of use. The degradation of coating layer may take place due to the peel-off from substrates, etc., resulting in the loss of material's strength, which stimulated the researchers to explore an alternative high mechanical strength material which can bond directly to natural bone. Therefore, composite biomaterials were chosen with desirable bonding properties than metal bone plates, thereby promising better bone fixation.

It is interesting to note that there are many definitions for biomaterials. Nevertheless, the definition proposed by Park was widely accepted. According to Park, biomaterial is a synthetic material used to replace a part of a living system or to function in intimate contact with living tissue. Similarly, according to National Institutes of Health Consensus Development Conference, held in 1982, biomaterial is any substance other than a drug, or combination of substances, synthetic, or natural in origin which can be

used for any period of time as a whole or as a part of the system that treats, augments or replaces any tissue, organ, or function of the body.

Some of the materials needed for biomaterials are metals and alloys, composites, glass and glass ceramics, polymers, etc. Similarly, the materials and devices such as sutures, needles, catheters, plates, tooth fillings, etc., are specifically designed and used for the treatment of diseases or injury are also termed as biomaterials. On the other hand, the materials which are produced by the living organism are known as biological materials. The synthetic materials/devices which are designed for applications like hearing aid and bandages get in contact with the skin are not termed as biomaterials.

Biomaterial research is an interdisciplinary area thus, it requires expertise from materials science, cell and molecular biology, experimental surgery, immunology, dentistry, maxillofacial, neurosurgery, obstetrics and gynaecology, ophthalmology, orthopaedics, otolaryngology, plastic and reconstructive surgery, thoracic and cardiovascular surgery, veterinary medicine, surgery, etc. In addition, the success of biomaterials depends on many factors namely, material properties, material design, and biocompatibility involving technical expertise. The materials scientists will take care about the material, design and biocompatibility to suit the clinical applications. On the other hand, the implementation of biomaterial implants, health condition of the patient and their activities are taken care by medical surgeons. Thus, the interdisciplinary work helps to identify the right choice of biomaterials for a particular clinical requirement.

Biomaterials are the special materials which provide an intimate contact with living tissues during their implantation with a minimum adverse reaction to the body. The degree of performance of the implant materials with body tissue is evaluated in terms of biocompatibility of implants. This phenomenon is known as biocompatibility. When the biomaterials are implanted, they function along with the living body provided the surrounding tissues accept the artificial implant. Thus, the implanted materials are having good compatibility with the living tissue to make bonding. Generally, when an implant material enters into the body, the responses of living body are like irritation, abnormal inflammatory response and insight allergic or immunological reaction.

The biomaterials used for implant applications should support the body healing rather than creating any life threatening infection. To optimise the biomaterials and their compositions, there are different techniques that facilitate the bioactivity and biocompatibility of the materials. Further, the biomaterials are optimised under sterile techniques which help to bring infection rates under control and help to recognise the impact of physical properties of implant material in the body. Therefore, it is essential that the biomaterials should be fabricated with good quality as well as hygiene. One has to be very careful in selecting the right material for the biomedical applications.

In this chapter, a brief discussion on the principle, properties, classifications, and applications of biomaterials are given. In addition, bioactive glasses and glass ceramics are discussed in details along with brief review of the state-of-the-art of work for biomedical applications.

1.2 CHARACTERISTICS OF BIOMATERIALS

To select the right materials for a specific application, one has to study the properties of biomaterials like physical, chemical, mechanical as well as optical

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About the Authors

DrV Rajendran, FUSI, FASI, FInstP, is the Director, Research & Development, KSR Group of Institutions and Centre for Nano Science and Technology (CNST), KS Rangasamy College of Technology (KSRCT), Tamil Nadu. He has more than 20 years of experience in teaching and research in the field of materials science and nanotechnology. Currently, he is working in the areas of nano metal oxides for different industrial applications; nanosilica from rice husk for applications such as textiles and biomedical, agriculture, and biomedical; nano bioactive glasses for biomedical applications; and developing nanoparticles from herbal plants for biomedical applications. He has served as visiting professor/scientist/invited speaker/paper presenter, in India and abroad which includes USA, Germany, Italy, France, Sweden, Finland, Singapore, Hong Kong, West Indies, Taiwan, etc. He has made remarkable achievement in measurement of temperature dependent mechanical properties of materials using online ultrasonic facilities.

He was the Principal Investigator of 14 completed sponsored research projects and is presently involved in many sponsored research projects from Nanomission DST, DRDO, and IGCAR, etc. Under his guidance, 6 scholars have completed their doctoral degrees and 10 scholars are pursuing. He has published more than 100 research papers in reputed International and National journals, 50 papers in conference proceedings, 17 refereed books, 8 edited proceedings, 2 R&D books, and 11 patents. He is a peer reviewer of many National and International journals.

Dr Rajendran has won many awards including *Tamil Nadu Scientist Award, Raman-Chanrdasekar Interdisciplinary Award, NDT Man of Year 2004, DAAD (2002)* from Germany, *INSA, TNSCST Young Scientist, DAE, BRNS Visiting Scientist* and *Outstanding Organiser Award.*

Col (Dr) SK Bhandari, MDS is presently working as Commanding Officer in Army Dental Corps, Military Dental Centre, Jabalpur and is classified specialist in the field of oral and maxillofacial surgery. Apart from research and development in the field of surgery, biomaterials, and biomedical instrumentation, his interests include trauma surgery, cosmetic surgery, implantology, and general dentistry. He has participated in four DRDO R&D projects pertaining to design and development of first indigenous dental implant system along with outlining the treatment modalities and protocols in the development of new biomaterials along with defining protocols for biomedical evaluation of these biomaterials.

He has to his credit more than 20 papers pertaining to various cost effective treatment modalities in the fields of dental implantology, maxillofacial reconstruction, and general dentistry.

About the Book

This monograph is intended to provide an overview of the principle, development, and practice of bioactive glasses for biomedical applications. It has five chapters which give in detail the structure and properties of biomaterials, various methods used for the synthesis of bioactive glasses, and characterisation techniques along with optimisation studies. It also provides the different applications of bioactive glasses and glass ceramics with practical illustrative applications. This book provides the basic understanding of synthesis, characterisation, and evaluation and justify the various practical usages of bioactive glasses and glass ceramics in various disciplines of surgery.

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