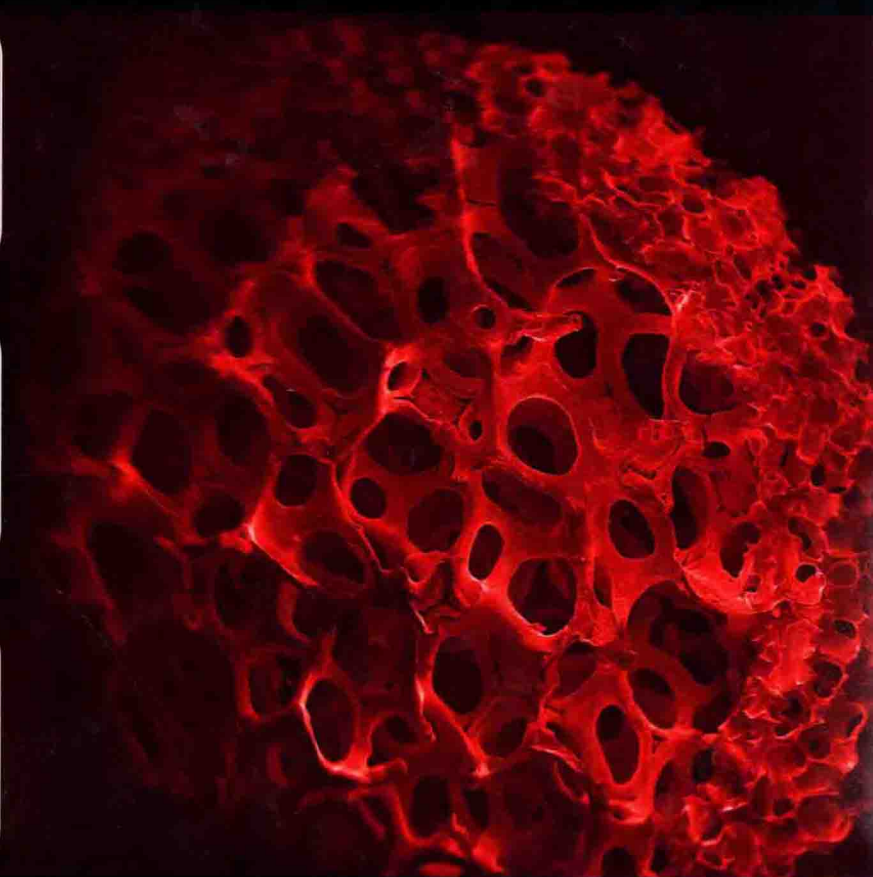
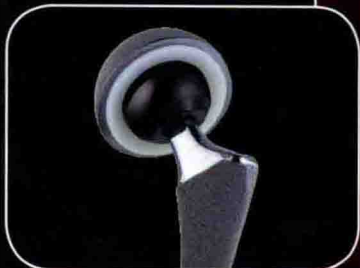


CAMBRIDGE TEXTS IN  
BIOMEDICAL  
ENGINEERING

# Introduction to Biomaterials

Basic Theory with Engineering Applications



C. Mauli Agrawal,  
Joo L. Ong, Mark R. Appleford  
and Gopinath Mani

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## **Introduction to Biomaterials**

This textbook gives students the perfect introduction to the world of biomaterials, linking the fundamental properties of metals, polymers, ceramics, and natural biomaterials to the unique advantages and limitations surrounding their biomedical applications.

- Clinical concerns such as sterilization, surface modification, cell–biomaterial interactions, drug delivery systems, and tissue engineering are discussed in detail, giving students practical insight into the real-world challenges associated with biomaterials engineering.
- Key definitions, equations and concepts are concisely summarized alongside the text, allowing students to quickly and easily identify the most important information.
- Bringing together elements from across the book, the final chapter discusses modern commercial implants, challenging students to consider future industrial possibilities.

Concise enough to be taught in a single semester, and requiring only a basic understanding of biology, this balanced and accessible textbook is the ideal introduction to biomaterials for students of engineering, materials science, and medicine.

**C. Mauli Agrawal** is the Vice President for Research at the University of Texas at San Antonio (UTSA), and the Peter Flawn Professor of Biomedical Engineering. Previously, he served as the Dean of the College of Engineering at UTSA. He specializes in orthopedic and cardiovascular biomaterials and implants and his inventions have been licensed to various companies. He is a member of the International College of Fellows of Biomaterials Science and Engineering, a Fellow of the American Institute for Medical and Biological Engineering, a former President of the Society for Biomaterials, and was awarded the 2010 Julio Palmaz Award for Innovation in Healthcare and the Biosciences.

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“This is a book that is destined to be a classic in biomaterials education. Written by leading bioengineers and scientists, it can serve not only as a textbook to support a semester-long undergraduate course, but also as an introduction to graduate-level classes. It is a well-written, comprehensive compendium of traditional and also modern knowledge on all aspects of biomaterials, and I am sure that both students and instructors will embrace it and use it widely.”

**Kyriacos A. Athanasiou**

*University of California, Davis*

I dedicate this work to my parents who taught me to love excellence, and to my wife and children (Sue, Ethan and Serena), who have always supported my pursuit of it.

C. Mauli Agrawal

To my family, who have put up with me all these years.

Joo L. Ong

I express my deepest appreciation for my wife Lindsey, best friend, greatest love, supplier of green limes and good joss.

Mark R. Appleford

I dedicate this work to my wife Priya Devendran, my daughter Manushri Gopinath, and my parents Mani and Bagyam Mani.

Gopinath Mani





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# Preface

Biomaterials have helped millions of people achieve a better quality of life in almost all corners of the world. Although the use of biomaterials has been common over many millennia, it was not until the twentieth century that the field of biomaterials finally gained recognition. With the advent of polymers, new processing and machining processes for metals and ceramics, and general advances in technology, there has been an exponential growth in biomaterials-related research and development activity over the past few decades. This activity has led to a plethora of biomaterials-based medical devices, which are now commercially available.

For students in the area of biomaterials, this is an especially exciting time. On the one hand, they have the opportunity to meet and learn from some of the stalwarts and pioneers of the field such as Sam Hulbert, one of the founders of the Society for Biomaterials (SFB). Other greats include Allan Hoffman and Buddy Ratner (biomaterials surfaces), Robert Langer (polymers and tissue engineering), Nicholas Peppas (hydrogels), Jack Lemons (orthopedic/dental implants), Joseph Salamone (contact lenses), and Julio Palmaz (intracoronary stents). Most of these individuals are still active in research and teaching. The authors of this book have been privileged to interact and learn from them in various forums, and students today have the same opportunities. On the other hand, with the current availability of sophisticated processing and characterization technologies, present day students also have the tools to take the field to unprecedented new levels of innovation.

This book has been written as an introduction to biomaterials for college students. It can be used either at the junior/senior levels of undergraduate education or at the graduate level for biomedical engineering students. It is best suited for students who have already taken an introductory course in biology. We have felt the need for a textbook that caters to *all* students interested in biomaterials and does not assume that every student intends to become a biomaterials scientist. This book is a balance between science and engineering, and presents both scientific principles and engineering applications. It does not assume that the student has a background in any particular field of study. Therefore, we first cover the basics of materials in Chapters 1 and 2 followed by basic biological principles in Chapter 3.

After presenting various techniques for the characterization of biomaterials in Chapter 4, we dedicate a chapter each to the discussion of metals, polymers, ceramics, and natural biomaterials (Chapters 5–8). Surface modification methods are presented in Chapter 9, followed by sterilization techniques in Chapter 10. The success of any biomaterial depends on the biological response to it and so protein chemistry, cell–biomaterial interactions, and the effect of biomaterials on tissue response are addressed in Chapter 11. The last three chapters (Chapters 12–14) cover the application of biomaterials in the clinical world; specifically drug delivery systems, tissue engineering, and clinical applications are presented and discussed.

This book has been designed to present enough material so that it can be comfortably covered during a regular length semester-long course. It should provide the student with a concise but comprehensive introduction to biomaterials and lays the foundation for more advanced courses.

The authors would like to thank the following individuals for assisting in a variety of ways in compiling this book: Jordan Kaufmann, Ethan Agrawal, Serena Agrawal, Tim Luukkonen, Amita Shah, Steve Lin, Angee Ong, Kevin Ong, Lisa Actis, Marcello Pilia, and Stefanie Shiels.

# Contents

*Preface*

*page xvii*

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Definitions	5
1.2	Changing focus	7
1.3	Types of bonds in materials	7
1.3.1	Ionic bonds	7
1.3.2	Metallic bonds	8
1.3.3	Covalent bonds	9
1.3.4	Secondary bonds	10
1.4	Types of materials	11
1.4.1	Ceramics	11
1.4.2	Metals	12
1.4.3	Polymers	14
1.4.4	Composites	14
1.5	Impact of biomaterials	15
1.6	Future of biomaterials	16
1.7	Summary	17
	References	17
	Problems	18
<b>2</b>	<b>Basic properties of materials</b>	<b>19</b>
2.1	Mechanical properties	20
2.1.1	Tensile testing	21
2.1.2	Compressive testing	26
2.1.3	Shear testing	27
2.1.4	Bend or flexural tests	27
2.1.5	Viscoelastic behavior	28
2.1.6	Ductile and brittle fracture	30
2.1.7	Stress concentration	32

2.1.8	Fracture toughness	33
2.1.9	Fatigue	34
2.2	Electrochemical properties	35
2.2.1	Corrosion	35
2.2.2	Types of corrosion	37
2.3	Surface properties	43
2.3.1	Contact angle	44
2.3.2	Hardness	44
2.4	Summary	45
	Suggested reading	45
	Problems	46
<b>3</b>	<b>Biological systems</b>	<b>48</b>
3.1	The biological environment	48
3.2	Genetic regulation and control systems	51
3.3	The plasma membrane	51
3.3.1	Membranes are phospholipid layers	52
3.4	Cytoskeleton and motility	53
3.5	Cell to cell communication pathways	55
3.6	Cell junctions	57
3.6.1	Tight junctions	57
3.6.2	Gap junctions	59
3.6.3	Adherens and desmosomes	61
3.7	Cell signaling pathways	62
3.7.1	Receptors as signaling sensors	63
3.7.2	Receptor classes	64
3.7.3	Second messengers and their activation/ deactivation	66
3.8	Biological testing techniques	68
3.8.1	Probe and labeling technologies	68
3.8.2	Examination of gene expression	69
3.8.3	The plasma membrane	69
3.8.4	Cytoskeleton and motility	70
3.8.5	Communication between cells	71
3.8.6	Mapping intracellular signaling	72
3.9	Summary	72
	Suggested reading	73
	Problems	73

<b>4</b>	<b>Characterization of biomaterials</b>	<b>74</b>
4.1	Contact angle	75
4.2	Infrared spectroscopy	80
4.2.1	Attenuated total reflection (ATR)	83
4.2.2	Specular reflectance	85
4.2.3	Infrared reflection absorption spectroscopy (IRRAS)	85
4.2.4	Diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS)	85
4.3	X-ray photoelectron spectroscopy	87
4.4	Secondary ion mass spectrometry	91
4.5	Atomic force microscopy	94
4.6	Scanning electron microscopy	98
4.7	Transmission electron microscopy	100
4.8	X-ray diffraction (XRD)	103
4.9	Chromatography	106
4.9.1	High performance liquid chromatography (HPLC)	106
4.9.2	Gel permeation chromatography (GPC)	108
4.10	Summary	110
	Suggested reading	110
	References	111
	Problems	111
<b>5</b>	<b>Metals: structure and properties</b>	<b>113</b>
5.1	Titanium and its alloys	114
5.1.1	Classification of Ti and its alloys based on crystallographic forms	116
5.1.2	Surface properties	119
5.1.3	Applications	119
5.2	Stainless steel	119
5.2.1	Martensitic stainless steels	120
5.2.2	Ferritic stainless steels	120
5.2.3	Austenitic stainless steels	120
5.2.4	Duplex stainless steels	122
5.2.5	Recent developments in stainless steel alloys	122
5.3	Cobalt–chromium alloys	123
5.3.1	ASTM F75	123
5.3.2	ASTM F799	125
5.3.3	ASTM F90	125
5.3.4	ASTM F562	126
5.4	Nitinol	126
5.5	Tantalum	128

5.6	Magnesium	129
5.7	Summary	130
	References	131
	Suggested reading	132
	Problems	132
<b>6</b>	<b>Polymers</b>	<b>134</b>
6.1	Molecular structure of polymers	135
6.1.1	Molecular weight	139
6.2	Types of polymerization	141
6.3	Physical states of polymers	142
6.3.1	Amorphous phase	142
6.3.2	Crystalline phase	144
6.4	Common polymeric biomaterials	146
6.4.1	Polyethylene	146
6.4.2	Polymethylmethacrylate (PMMA)	147
6.4.3	Poly(lactic acid) (PLA) and poly(glycolic acid) (PGA)	150
6.4.4	Polycaprolactone (PCL)	152
6.4.5	Other biodegradable polymers	153
6.4.6	Polyurethanes	153
6.4.7	Silicones	154
6.5	Hydrogels	155
6.5.1	Synthesis of hydrogels	159
6.5.2	Properties of hydrogels	160
6.5.3	Applications	160
6.6	Nanopolymers	161
6.7	Summary	162
	References	163
	Suggested reading	163
	Problems	163
<b>7</b>	<b>Ceramics</b>	<b>165</b>
7.1	General properties	166
7.2	Classifications	167
7.2.1	Classification based on form	167
7.2.2	Classification based on composition	168
7.2.3	Classification based on reactivity	169
7.3	Bioceramics	169
7.3.1	Silicate glass	170
7.3.2	Alumina ( $\text{Al}_2\text{O}_3$ )	174

7.3.3	Zirconia ( $\text{ZrO}_2$ )	177
7.3.4	Carbon	179
7.3.5	Calcium phosphates (CaP)	180
7.3.6	Hydroxyapatite (HA)	183
7.3.7	Tricalcium phosphate (TCP)	186
7.3.8	Calcium sulfate ( $\text{CaSO}_4 \cdot \text{H}_2\text{O}$ )	187
7.3.9	Bioactive glass	188
7.4	Nanoceramics	189
7.5	Summary	195
	References	196
	Suggested reading	196
	Problems	196
<b>8</b>	<b>Natural biomaterials</b>	<b>198</b>
8.1	Collagen	199
8.2	Elastin	204
8.3	Silk	207
8.4	Chitosan	210
8.5	Cellulose	213
8.6	Alginate	217
8.7	Hyaluronan	223
8.8	Chondroitin sulfate	226
8.9	Coral	228
8.10	Summary	231
	References	231
	Suggested reading	231
	Problems	232
<b>9</b>	<b>Surface modification</b>	<b>233</b>
9.1	Abrasive blasting	234
9.2	Plasma glow discharge treatments	237
9.2.1	Direct current glow discharge	239
9.2.2	Alternating current glow discharge	240
9.2.3	Capacitively coupled radiofrequency glow discharge	241
9.2.4	Inductively coupled radiofrequency glow discharge	242
9.3	Thermal spraying	243
9.4	Physical vapor deposition (PVD)	251
9.4.1	Evaporative deposition	252
9.4.2	Pulsed laser deposition	253
9.4.3	Sputter deposition	254

9.5	Chemical vapor deposition (CVD)	261
9.6	Grafting	264
9.7	Self-assembled monolayer (SAM)	266
9.7.1	Patterning of self-assembled monolayers	271
9.8	Layer-by-layer (LbL) assembly	274
9.8.1	Different layer-by-layer (LbL) assembly techniques	277
9.9	Summary	279
	References	279
	Suggested reading	280
	Problems	280
<b>10</b>	<b>Sterilization of biomedical implants</b>	<b>282</b>
10.1	Common terminology	282
10.2	Steam sterilization	283
10.3	Ethylene oxide sterilization	285
10.4	Gamma radiation sterilization	287
10.5	Other sterilization methods	289
10.5.1	Dry heat sterilization	289
10.5.2	Formaldehyde and glutaraldehyde treatments	290
10.5.3	Phenolic and hypochloride solution treatments	290
10.5.4	Ultraviolet (UV) radiation	290
10.5.5	Electron beam sterilization	291
10.6	Recently developed methods	291
10.6.1	Low temperature gas plasma treatment	291
10.6.2	Gaseous chlorine dioxide treatment	292
10.7	Summary	292
	References	293
	Suggested reading	293
	Problems	294
<b>11</b>	<b>Cell-biomaterial interactions</b>	<b>295</b>
11.1	The extracellular environment	297
11.2	Extracellular matrix mimics	309
11.3	Cell interactions with non-cellular substrates	309
11.4	Biocompatibility testing and techniques	314
11.4.1	Immunostaining techniques for studying cell-ECM interactions	316
11.4.2	Profiling a cell line for its ECM binding characteristics	317
11.4.3	Immunoprecipitation and Western blotting	318



11.5	Summary	319
	Reference	319
	Suggested reading	319
	Problems	320
<b>12</b>	<b>Drug delivery systems</b>	<b>321</b>
12.1	Diffusion controlled drug delivery systems	323
12.1.1	Membrane controlled reservoir systems	323
12.1.2	Monolithic matrix systems	324
12.2	Water penetration controlled drug delivery systems	325
12.2.1	Osmotic pressure controlled drug delivery systems	326
12.2.2	Swelling controlled drug delivery system	327
12.3	Chemically controlled drug delivery systems	328
12.3.1	Polymer–drug dispersion systems	328
12.3.2	Polymer–drug conjugate systems	329
12.4	Responsive drug delivery systems	331
12.4.1	Temperature-responsive drug delivery systems	331
12.4.2	pH-responsive drug delivery systems	332
12.4.3	Solvent-responsive drug delivery systems	333
12.4.4	Ultrasound-responsive drug delivery systems	333
12.4.5	Electrically responsive drug delivery systems	334
12.4.6	Magnetic-sensitive drug delivery systems	334
12.5	Particulate systems	335
12.5.1	Polymeric microparticles	335
12.5.2	Polymeric micelles	336
12.5.3	Liposomes	336
12.6	Summary	337
	References	339
	Suggested reading	339
	Problems	340
<b>13</b>	<b>Tissue engineering</b>	<b>341</b>
13.1	Tissue engineering approaches	342
13.1.1	Assessment of medical need	342
13.1.2	Selecting a tissue engineering strategy	343
13.2	Cells	344
13.2.1	Stem cells	345
13.2.2	Biopreservation of cells	347
13.3	Scaffold properties	349
13.4	Fabrication techniques for polymeric scaffolds	350