# Contents

*Preface*  
List of Contributors

## Part I  Fundamentals of Peptide Materials

1  **Physics of Peptide Nanostructures and Their Nanotechnology Applications**  
*Nadav Amdursky, Peter Beker and Gil Rosenman*  
1.1 Introduction to Peptide Nanotubes  
1.2 Optical Properties and Quantum Confinement of FF-based Nanostructures  
1.3 Odd-Tensor Related Physical Properties  
1.4 Thermal Induced Phase Transition in Peptide Nanotubes  
  1.4.1 Changes in the Structure Properties during the Phase Transition Process  
  1.4.2 Phase Transition Classification of the Thermally Induced Process  
1.5 Deposition Techniques of PNT  
  1.5.1 Wet Deposition Techniques  
  1.5.2 Dry Deposition Technique  
1.6 Applications of PNTs  
  1.6.1 PNTs for Nanotechnological Applications  
  1.6.2 PNTs as a Deposition Scaffold  
1.7 Conclusion  
References

2  **Chemistry of Peptide Materials: Synthetic Aspects and 3D Structural Studies**  
*Fernando Formaggio, Alessandro Moretto, Marco Crisma and Claudio Toniolo*  
2.1 Introduction  
2.2 Synthesis of Difficult Peptide Sequences  
2.3 Peptide (Amide) Bond  
2.4 Peptide Torsion Angles  
2.5 Peptide Secondary Structures  
  2.5.1 α-Helix  
  2.5.2 3_{10}-Helix  
  2.5.3 2.2_1-Helix  
  2.5.4 Pleated-Sheet β-Structures
3 Conformational Aspects and Molecular Dynamics Simulations of Peptide Hybrid Materials: From Methods and Concepts to Applications

Carlos Alemán, Oscar Bertran, Jordi Casanovas, Juan Torras, Guillermo Revilla-López and David Zanuy

3.1 Computational Chemistry
3.2 Quantum Mechanical Calculations: Concepts
  3.2.1 Ab Initio Methods
  3.2.2 Semiempirical Methods
  3.2.3 Density Functional Theory
  3.2.4 Solvent Effects in Quantum Mechanical Calculations
3.3 Quantum Mechanical Calculations on Hybrid Peptide Materials: Some Examples
3.4 NCAD: An Information Management System of Quantum Mechanical Calculations on Noncoded Amino Acids for Peptide Design
3.5 Molecular Mechanics Calculations: Concepts
  3.5.1 Force Fields
  3.5.2 Energy Minimization
  3.5.3 Molecular Dynamics
  3.5.4 Boundary Conditions, Pair-List and Long-Range Interactions
  3.5.5 Temperature and Pressure
3.6 Molecular Dynamics Simulations on Peptides
  3.6.1 Construction of the Molecular Model
  3.6.2 Practical Strategies for the Application of Molecular Dynamics Techniques
  3.6.3 Analysis of the Simulation Data
  3.6.4 Peptide Dynamics
  3.6.5 Hybrid Peptide Dynamics
3.7 Summary

Acknowledgements
References

4 Peptronics: Peptide Materials for Electron Transfer

Emanuela Gatto and Mariano Venanzi

4.1 Introduction
4.2 Electron Transfer through Peptide Scaffolds in Solution
  4.2.1 Theoretical Background
  4.2.2 Seminal Experimental Results
4.3 Electron Transfer through Supported Peptide Matrices
  4.3.1 Theoretical Background
  4.3.2 Seminal Experimental Results
Part II  Peptide Nanostructures  149

5  Molecular Architecture with Peptide Assembling for Nanomaterials  151
Shunsaku Kimura and Motoki Ueda

5.1 Introduction  151
5.2 Peptide Vesicles  152
5.2.1 Peptosome  153
5.2.2 Polypeptide as a Hydrophilic Block (AB Type and ABA Type)  153
5.2.3 Block Polypeptides Having a Hydrophobic Polypeptide  154
5.2.4 Other ABA Triblock Copolymers  154
5.2.5 Hyper-branched Polymers and Dendrimers  155
5.2.6 Triskelion Structure  155
5.2.7 Cyclic Peptide as Template for Amphiphilicity  155
5.2.8 Lipid-Like Structure  155
5.3 Peptide Building Blocks  157
5.3.1 Oligopeptides  157
5.3.2 Dipeptides  158
5.3.3 β-Peptides  158
5.3.4 Naturally Occurring Peptides  158
5.4 Peptide Architecture  159
5.4.1 Protein Cages  159
5.4.2 Ion-Complex for Self-Assembling  160
5.4.3 Stereo-Complex for Self-Assembling  160
5.4.4 Inside-out Morphology Transformation  161
5.5 Function of Peptide Assemblies  161
5.6 Tumor Imaging with Peptide Nanocarrier  163
5.7 Perspectives  167
References  168

6  Principles of Shape-Driven Nanostructure Design via Self-Assembly of Protein Building Blocks  171
Idit Buch, Chung-Jung Tsai, Carlos Alemán and Ruth Nussinov

6.1 Introduction  172
6.2 Self-Assembly into Preferred Shapes  172
6.2.1 Why Does a Given Building Block Prefer to Self-Assemble into a Particular Shape?  172
6.2.2 The Self-Assembly Formation Mechanism – A Lesson from Lipid Tubules  177
6.2.3 Experimental Results  177
6.3 Designing Protein Nanotubes  180
## 6 Contents

6.3.1 Shape-Driven Design 180  
6.3.2 Structural Properties of Protein Nanotubes and a Design Scheme 181  
6.3.3 Incorporation of Nonproteinogenic Amino Acids 183  
6.3.4 MD Simulations as a Testing Tool for Novel Designs 184  
6.4 Summary and Outlook 185  
Acknowledgements 186  
References 186

## 7 Peptide-Based Soft Spherical Structures 191  
K. Vijaya Krishna, Nidhi Gour and Sandeep Verma

7.1 Introduction 191  
7.2 Short Peptide Sequences 192  
7.3 Amphiphilic Peptides 200  
7.4 Peptide–Polymer Hybrids 205  
7.5 Future Outlook 209  
References 211

## Part III Peptide Conjugates and Hybrid Materials 217

## 8 Peptide-Based Carbon Nanotube Dispersal Agents 219  
Anton S. Klimenko and Gregg R. Dieckmann

8.1 Introduction 220  
8.2 α-Helical Surfactant Peptides 222  
8.2.1 Model for Helical Peptide Dispersion of Nanotubes 224  
8.2.2 Peptide–Nanotube Interactions 224  
8.2.3 Peptide–Nanotube Complex Structure 227  
8.3 β-Strand Surfactant-Like Peptides 229  
8.4 Extended Peptides 231  
8.5 Amorphous Peptides 233  
8.6 Cyclic Peptides 234  
8.6.1 Reversible Cyclic Peptides 235  
8.7 Summary and Outlook 237  
Acknowledgements 239  
References 239

## 9 Nanosized Vectors for Transfection Assembled from Peptides and Nucleic Acids 247  
Burkhard Bechinger

9.1 Introduction 248  
9.2 Condensation of Nucleic Acids by Cationic Peptides and Other Macromolecules 250  
9.3 The Size and Shape of Transfection Complexes 251  
9.4 Cellular Targeting by Specific Ligands 252  
9.5 Enhancing the Cellular Uptake of Nanocomplexes 252  
9.6 Assuring Endosomal Escape 253
Contents

9.7 A Family of Multifunctional Peptide Sequences 255
9.8 Delivery to the Nucleus and Other Intracellular Compartments 257
9.9 Combining Different Functionalities into Complex Nanovehicles 257
Acknowledgements 259
References 259

10 Properties of Disubstituted Ferrocene–Peptide Conjugates: Design and Applications 265
Sanela Martić, Samaneh Beheshti and Heinz-Bernhard Kraatz

10.1 Introduction 266
10.2 Structural Considerations and Properties 266
10.3 Fe–Peptides to Probe Interactions 274
10.3.1 Interactions with Ions 274
10.3.2 Interactions with Other Molecular Targets 280
10.3.3 Probing Peptide–Protein Interactions 280
10.4 Conclusions 283
References 284

11 Mechanisms of Adsorption of Short Peptides on Metal and Oxide Surfaces 289
Vincent Humblot, Jessem Landoulsi and Claire-Marie Pradier

11.1 Introduction 290
11.2 Why Studying the Interaction of Short Peptides with Solid Surfaces? 291
11.3 Metal and Oxide Surfaces 292
11.4 Factors Influencing Peptide Adsorption 293
11.4.1 Driving Force 293
11.4.2 Influence of Intrinsic Properties 294
11.4.3 Influence of External Parameters 294
11.5 Adsorption at the Solid/Gas interface 295
11.5.1 Adsorption of Dipeptides 295
11.5.2 Adsorption of Tripeptides 299
11.6 Adsorption at the Solid/Liquid Interface 303
11.7 Conclusions and Guidelines for the Future 307
References 308

Part IV Applications of Peptide Materials 313

12 Bioactive Rosette Nanotubes for Bone Tissue Engineering and Drug Delivery 315
Rachel L. Beingessner, Alaaeddin Alsbaiee, Baljit Singh, Thomas J. Webster and Hicham Fenniri

12.1 Introduction 316
12.2 Rosette Nanotubes (RNTs) 317
12.2.1 RNT Design 317
12.2.2 RNT Functionalization 320
# 13 Peptide Secondary Structures as Molecular Switches

*Fernando Formaggio, Alessandro Moretto, Marco Crisma and Claudio Toniolo*

13.1 Introduction 360
13.2 Classical Secondary Structures Switches 360
  13.2.1 $\alpha$-Helix/$\beta$-Pleated Sheet Switch 360
  13.2.2 Type-I Poly-(l-Pro)$_n$/Type II Poly-(l-Pro)$_n$ Switch 363
13.3 Recently Discovered Secondary Structure Switches 365
  13.3.1 The $3_{10}$-Helix/$\alpha$-Helix Switch 365
  13.3.2 The 2.05-Helix/$3_{10}$-Helix Switch 371
13.4 Conclusions 376
References 378

# 14 Peptide Nanostructured Conjugates for Therapeutics: The Example of P140 Peptide for the Treatment of Systemic Lupus Erythematosus

*Yves Frère, Louis Danicher and Sylviane Muller*

14.1 Introduction 386
14.2 Noninvasive Routes of Peptide Administration 387
  14.2.1 The Transcutaneous Route 387
  14.2.2 The Transmucosal Routes for Peptide Delivery 387
  14.2.3 The Oral Route 388
14.3 Encapsulation of Peptides and Proteins for Oral Delivery 390
  14.3.1 Lipidic Vectors 390
  14.3.2 Polymeric Vectors 391
  14.3.3 The Vector for the Oral Route 397
14.4 P140 Peptide Nanostructured Complex for the Treatment of Systemic Lupus Erythematosus 399
  14.4.1 The Therapeutic Peptide P140 399
  14.4.2 Development of Nanoparticles Containing Hyaluronic Acid Associated to P140 Peptide (HA-P140) 400
  14.4.3 The Effect of HA-P140 Nanoparticles in Healthy and Lupus Mice 407
14.5 General Comments 412
Acknowledgements 412
References 412