NANOSCIENCE AND NANOTECHNOLOGY IN ENGINEERING

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Preface

Nanoscience and nanotechnology involve studying and working with materials at the nanometer scale, and stretch across the whole spectrum of science and technology. Generally speaking, nanoscience concentrates on the fundamental relationships between the physical properties of materials and their nanoscale dimensions, and the underlying sciences for nanoscale synthesis, assembly and characterization. Nanotechnology mainly deals with the design, fabrication and application of nanomaterials. The research and development in nanoscience and nanotechnology require the collaborations between researchers from different disciplines, such as physics, chemistry, materials science, electrical engineering, mechanical engineering and biomedical engineering. The ultimate goal of nanoscience and nanotechnology is to develop materials, devices and systems that outperform the ones developed based on the conventional sciences and technologies, and to create completely novel functionalities.

The advances in nanoscience and nanotechnology exhibit great varieties, and the nanoscience and nanotechnology in engineering is one of the most active and the most important areas in the field of nanoscience and nanotechnology. It directly relates the research activities in nanoscience and nanotechnology to industries and daily life, and numerous nanomaterials, nanodevices and nanosystems for various engineering purposes have been developed and applied for human betterment. Many universities are developing and delivering courses on this area, and we therefore realize the urgent need for an appropriate textbook.

This is the first book that systematically discusses the engineering aspects of nanoscience and nanotechnology from the fundamental level, and includes the breakthrough milestones and the latest developments in this area. It is specially tailored to be a textbook for undergraduates, graduates and those seeking short-term professional trainings. It may also

serves as a reference desk resource for both academic and industrial researchers interested in this area.

This book consists of eight chapters. Each chapter provides an overview of a specific topic with examples chosen primarily for their educational purposes, and it is organized in a way that fits readers from different science and engineering disciplines. Students are encouraged to expand on the topics discussed in this book by reading the references provided at the end of each chapter.

The first chapter provides the fundamental knowledge of nanoscience and nanotechnology. It starts with introducing the origins of nanoscience and nanotechnology, followed by discussing the general schemes and classification of nanotechnology. The challenges in nanoscience and nanotechnology are analyzed subsequently. Chapter 2 discusses the physical and biological aspects of nanoscience and nanotechnology. After introducing the basics of quantum physics and the fundamentals of nanophysics, the crystal structures and physical properties of materials are discussed, followed by the physical aspects of nanochemistry. After that, the biological aspects of nanoscience and nanotechnology are discussed.

Chapter 3 outlines the technologies for nanoscale fabrication and characterization. These techniques provide the experimental bases for nanoscience and nanotechnology in engineering. This chapter starts with the approaches for nanoscale fabrications, including bottom-up approach and top-down approach. The techniques for characterizing the unique properties of nanomaterials are discussed subsequently, including atomic structure, chemical composition, size, shape and surface area, and the properties of nanoparticles in biological systems.

Based on the fundamental concepts, theoretical backgrounds and experimental techniques discussed in the first three chapters, the following five chapters discuss five important topics on nanoscience and nanotechnology in engineering, including carbon nanomaterials, nanostructured materials, polymer nanotechnology, nanocomposites and organic electronics.

Among different kinds of nanomaterials, carbon nanomaterials are the most popular. Chapter 4 presents a systematic discussion on various types of carbon nanomaterials, including fullerenes, carbon nanotubes

and carbon nanofoams. For each type of carbon nanostructures, their synthesizing methods, specific properties and typical applications are discussed.

The properties of nanomaterials are strongly dependent on their structures at the nanometer scale. Chapter 5 deals with the synthesis, properties and applications of typical nanostructured materials, including nanopowders, nanoporous materials, nanodusts, nanowires and nanotubes. Special attention is paid on three-dimensional zinc oxide nanostructures.

Chapter 6 concentrates on a special kind of soft nanotechnology, polymer nanotechnology. After introducing electroactive polymers, the fabrication of polymer nanowires, polymer nanotubes, and three-dimensional polymer nanostructures are discussed.

Due to their unprecedented combinations of properties, nanocomposites are widely used for engineering applications. Various types of nanocomposites are discussed in Chapter 7, mainly including ceramic matrix nanocomposites, metal matrix nanocomposites, magnetic nanocomposites, polymeric nanocomposites, and nano-bio-composites. At the end of this chapter, a brief discussion is made on smart and intelligent nanocomposites, which are regarded as the future of materials science and technology.

The use of individual molecules, such as carbon nanotubes or other organic compounds, as electronic components offers promising alternatives to current microelectronic devices. Chapter 8 deals with nanoscale electronics with a focus on organic electronics. After discussing the fabrication and properties of pentacene thin films, typical organic sensors and their applications are discussed, with emphasis laid on strain sensors and ion-sensitive field effect transistors.

In preparing this book, it is always kept in our mind to relate the speculative concepts in nanoscience and nanotechnology to practical research and development activities. This book contains our many years of experiences and achievements in this area, and a lot of technical details are released for the first time.

Some of the materials for this book are taken from many lectures and courses we presented around the world. The valuable comments from the participants of these lectures and courses greatly enriched the contents of

this book. Meanwhile, we would like to indicate that this book is a compilation of the work carried out by many researchers, and we greatly appreciate their valuable contributions in this area. We are also very grateful to the publisher and the staff for their constant encouragement, guidance and support during this project.

There are many people to whom we owe our gratitude for helping us in this process. However, space dictates that only a few of them can receive formal acknowledgements. Our foremost appreciation goes to the research professors and staff of the High Density Electronics Center, University of Arkansas, Fayetteville, in particular, Dr. T. Ji, Dr. H. Yoon and Dr. J. Xie.

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Contents

Preface	v
About the Authors	ix
1. Introduction	1
1.1 What is nanoscience and nanotechnology?	2
1.1.1 Natural and artificial nanoparticles	3
1.1.2 Nanotechnology in ancient time	5
1.1.3 Feynman, Drexler and Taniguchi	7
1.1.4 Moore's law	7
1.2 Effects of making into small	8
1.2.1 Size dependence of materials properties.....	10
1.2.2 Special properties of nanomaterials.....	11
1.2.2.1 Structural properties.....	11
1.2.2.2 Thermal properties	11
1.2.2.3 Chemical properties	12
1.2.2.4 Mechanical properties	12
1.2.2.5 Magnetic properties	13
1.2.2.6 Optical properties	13
1.2.2.7 Electronic properties	13
1.2.2.8 Biological properties	15
1.3 General themes and classification of nanotechnology.....	15
1.3.1 General themes of nanotechnology	15
1.3.1.1 Characterization tools	16
1.3.1.2 Nanoscale science	16
1.3.1.3 Molecular level computation.....	16
1.3.1.4 Fabrication and processing technology.....	16
1.3.2 Classification of nanotechnology	17
1.4 Challenges in nanoscience and nanotechnology	17
1.4.1 Technological challenge.....	17
1.4.2 Societal and ethical challenge	18
1.4.3 Business driven economy	20
1.4.4 Risk and uncertainty	21
1.4.5 Security and military implications	22
1.4.6 Emerging concern from nanoparticles	22

2. Physical and Biological Aspects of Nanoscience and Nanotechnology	27
2.1 Basics of quantum physics	27
2.2 Fundamentals of nanophysics	28
2.2.1 Electron levels for atoms and solids	29
2.2.1.1 Atoms	29
2.2.1.2 Solids	31
2.2.2 Electron levels for nanostructures	33
2.2.2.1 Free electron	34
2.2.2.2 Electron in a finite potential well	34
2.2.2.3 Electron in an infinite potential well	35
2.2.2.4 Schrödinger equations	35
2.2.3 Density of states and confinement	37
2.2.3.1 Zero-dimensional solid	38
2.2.3.2 One-dimensional quantum wire	38
2.2.3.3 Two-dimensional thin film	39
2.2.3.4 Particle in a three-dimensional box	40
2.3 Crystal structures and physical properties	40
2.3.1 Cubic crystal lattice structures	42
2.3.2 Symmetry in crystals	43
2.3.3 Bravais lattices and point/space groups	45
2.3.4 Quasicrystals	45
2.3.5 Liquid crystals	45
2.4 Physical aspects of nanochemistry	47
2.4.1 Nomenclature and periodic table of elements	47
2.4.2 Surface energy of nanostructured materials	48
2.5 Bionanoscience and bionanotechnology	51
2.5.1 Basic concepts	51
2.5.2 Lipids	53
2.5.3 Proteins	53
2.5.4 Biomimetic polypeptides	55
2.5.5 Viruses	56
2.5.6 Deoxyribonucleic acid	56
2.5.6.1 Structures of DNA	57
2.5.6.2 Nanoparticles and DNA	59
2.5.6.3 DNA electronics	60
2.5.6.4 DNA computing	60
2.5.7 Biological neuronal networks	61
2.5.8 Artificial neuronal networks	63
2.5.8.1 Neural networks and conventional computers	63
2.5.8.2 Biological neuronal cells on silicon	65
2.5.9 Molecular biomimetics	65

3. Nanoscale Fabrication and Characterization	71
3.1 Nanoscale fabrication	71
3.1.1 Bottom-up approach	72
3.1.1.1 Chemical synthesis	72
3.1.1.2 Self-assembly	73
3.1.1.3 Positional assembly	74
3.1.2 Top-down approach	74
3.1.2.1 Photolithography	75
3.1.2.2 Electron beam lithography	76
3.1.2.3 Focused ion beam lithography	78
3.1.2.4 Dip-pen nanolithography	80
3.1.2.5 Extreme ultraviolet lithography	81
3.1.2.6 Nanoimprint lithography	82
3.1.2.7 Contact lithography	85
3.1.2.8 X-ray lithography	85
3.1.2.9 Lift-off lithography	87
3.1.2.10 Soft lithography	88
3.2 Characterization of nanomaterials	89
3.2.1 Atomic structure and chemical composition	90
3.2.1.1 Vibrational spectroscopies	90
3.2.1.2 Nuclear magnetic resonance	91
3.2.1.3 X-ray and UV spectroscopies	91
3.2.1.4 X-ray and neutron diffraction	93
3.2.2 Size, shape and surface area	94
3.2.2.1 Electron microscopy	94
3.2.2.2 BET and pycnometry	96
3.2.2.3 Epiphanimeter	97
3.2.2.4 Zeta potential analyzer	97
3.2.2.5 Laser granulometry	98
3.2.2.6 Elliptically polarized light scattering	98
3.2.2.7 Gas adsorption	99
3.2.2.8 Positron annihilation	100
3.2.2.9 Mercury porosimetry	101
3.2.3 Nanoparticles in biological systems	101
4. Carbon Nanomaterials	107
4.1 Carbon allotropes	107
4.2 Fullerenes	109
4.2.1 Molecule structures	109
4.2.2 Physical and chemical properties	111
4.2.3 Synthesis methods	113

4.2.3.1	Electric arc method	113
4.2.3.2	Laser ablation method	113
4.2.3.3	Solar energy method.....	114
4.2.4	Functionalization.....	114
4.2.5	Possible risks	115
4.3	Carbon nanotubes	116
4.3.1	Why carbon nanotubes?	116
4.3.2	Structure of carbon nanotubes	117
4.3.3	Special properties of carbon nanotubes	118
4.3.3.1	Chemical reactivity	119
4.3.3.2	Electrical conductivity.....	119
4.3.3.3	Optical activity	120
4.3.3.4	Vibrational properties	120
4.3.3.5	Mechanical strength	120
4.3.3.6	Specific heat and thermal conductivity	121
4.3.4	Synthesis of carbon nanotubes.....	121
4.3.4.1	Arc discharge method	122
4.3.4.2	Laser ablation method	124
4.3.4.3	Chemical vapor deposition method	125
4.3.4.4	Catalyzed decomposition method	129
4.3.5	Purification of carbon nanotubes	133
4.3.5.1	Oxidation	133
4.3.5.2	Acid treatment	133
4.3.5.3	Annealing	134
4.3.5.4	Ultrasonication	134
4.3.5.5	Magnetic purification.....	134
4.3.5.6	Microfiltration	134
4.3.5.7	Cutting	135
4.3.5.8	Functionalization.....	135
4.3.5.9	Chromatography	135
4.3.6	Defects of carbon nanotubes.....	136
4.4	Carbon nanofoam	136
4.4.1	Synthesis	137
4.4.2	Properties.....	137
4.5	Applications.....	138
4.5.1	Fullerenes.....	139
4.5.2	Carbon nanotubes	139
4.5.2.1	Energy storage	139
4.5.2.2	Hydrogen storage.....	139
4.5.2.3	Lithium intercalation	140
4.5.2.4	Electrochemical supercapacitors	141
4.5.2.5	Molecular devices with CNTs	141

4.5.2.6 Nanoelectromechanical systems	142
4.5.2.7 Composite materials.....	145
4.5.2.8 Templates	146
4.5.2.9 Neuron growth	146
4.5.3 Carbon nanofoam	147

5. Nanostructured Materials	153
5.1 Introduction	153
5.1.1 Classifications of nanostructured materials	153
5.1.2 Top-down and bottom-up synthesis approaches.....	154
5.2 Nanopowders	157
5.2.1 Properties of nanopowders	157
5.2.2 Synthesis of nanopowders.....	158
5.2.2.1 Metal nanopowders.....	158
5.2.2.2 Metal oxide nanopowders	159
5.3 Nanoporous materials	161
5.3.1 Properties of nanoporous materials	161
5.3.2 Synthesis of nanoporous materials.....	162
5.3.2.1 Silica.....	163
5.3.2.2 Transition metal oxides.....	164
5.3.2.3 Metal sulfides	164
5.3.2.4 Aluminum phosphates	165
5.3.2.5 Silicon nitrides	165
5.3.2.6 Anodic aluminum oxides	165
5.3.2.7 Metals	166
5.4 Nanodusts.....	166
5.4.1 Nanodusts in nature	166
5.4.2 Synthesis of nanodusts	167
5.5 Nanowires	168
5.5.1 Classifications of nanowires.....	168
5.5.2 Synthesis of nanowires	169
5.6 Nanotubes.....	171
5.6.1 Classification of nanotubes.....	172
5.6.2 Synthesis of inorganic nanotubes	172
5.7 Zinc oxide nanostructures	174
5.8 Applications.....	176
5.8.1 Nanopowders	176
5.8.2 Nanoporous materials	178
5.8.3 Nanodusts	179
5.8.3.1 Energy	179
5.8.3.2 Pollution control	180

5.8.3.3	Nuclear protection.....	180
5.8.3.4	Composite reinforcement.....	180
5.8.4	Nanowires.....	181
5.8.5	Inorganic nanotubes.....	181
5.8.5.1	Control of bio-interactions.....	183
5.8.5.2	Growth of neuron cells.....	184
5.8.6	ZnO nanostructures.....	185
6.	Polymer Nanotechnology	191
6.1	Electroactive polymers.....	191
6.1.1	Polypyrrole.....	191
6.1.2	Nafion.....	192
6.2	Fabrication of polymer nanowires.....	192
6.2.1	Electrochemical polymerization.....	193
6.2.2	Critical point drying.....	193
6.3	Fabrication of polymer nanotubes.....	197
6.3.1	Blank polymer nanotubes.....	198
6.3.2	Metal nanowires encapsulated in polymer nanotubes.....	203
6.4	Fabrication of 3D polymer microstructures.....	205
6.4.1	Microstereolithography.....	205
6.4.2	Two-photon microstereolithography.....	207
7.	Nanocomposites	215
7.1	Nanoscale reinforcements.....	216
7.1.1	Nanoscale carbons.....	216
7.1.2	Nano clays.....	217
7.1.3	Equi-axed nanoparticles.....	218
7.2	Ceramic matrix nanocomposites.....	219
7.2.1	Synthesis methods.....	220
7.2.1.1	Sol-gel processing.....	221
7.2.1.2	Chemical vapor deposition.....	221
7.2.1.3	Mechanical alloying.....	221
7.2.1.4	Thermal spraying.....	222
7.2.2	CNT reinforced CNCs.....	223
7.2.3	Thin film nanocomposites.....	224
7.2.3.1	Granular films.....	224
7.2.3.2	Multi-layer films.....	225
7.3	Metal matrix nanocomposites.....	225
7.4	Magnetic nanocomposites.....	227
7.4.1	Particle-dispersed magnetic nanocomposites.....	227
7.4.2	Magnetic multi-layer films.....	227

7.5	Polymeric nanocomposites	228
7.5.1	Synthesis of polymeric nanocomposites	230
7.5.1.1	Melt mixing method.....	230
7.5.1.2	Solution mixing	230
7.5.1.3	<i>In-situ</i> polymerization	231
7.5.1.4	<i>In-situ</i> particle processing	231
7.5.1.5	Thermal spray method.....	231
7.5.1.6	Template method.....	231
7.5.2	Typical properties of polymeric nanocomposites.....	232
7.5.2.1	Mechanical properties	232
7.5.2.2	Glass transition and relaxation behavior.....	232
7.5.2.3	Abrasion and wear resistance	233
7.5.2.4	Permeability.....	233
7.5.2.5	Dimensional stability	234
7.5.2.6	Thermal stability and flammability.....	234
7.5.2.7	Resistivity, permittivity and breakdown strength	235
7.5.2.8	Optical clarity	235
7.5.3	Clay reinforced PNCs	236
7.5.4	CNT reinforced PNCs.....	237
7.5.5	Rubber matrix nanocomposites.....	237
7.5.6	Stealth PNCs.....	238
7.6	Nano-bio-composites.....	239
7.6.1	Botanically synthesized nanoparticles	240
7.6.2	Biologically synthesized nanostructures	240
7.7	Smart and intelligent nanocomposites.....	241
8.	Organic Electronics	245
8.1	Introduction	245
8.2	Morphology of pentacene thin film	248
8.3	OTFT fabrication.....	250
8.4	Typical organic sensors.....	255
8.5	Strain sensors	257
8.5.1	Carbon nanotube synthesis	257
8.5.1.1	Apparatus	257
8.5.1.2	Catalyst preparation	258
8.5.1.3	Microwave CVD synthesis and purification	259
8.5.1.4	Electron microscope observation.....	259
8.5.2	Organic strain sensor fabrication	260
8.5.3	Sensor measurement	262
8.6	Poly-3-hexylthiophene based ISFET sensors	264
8.6.1	Biomedical applications.....	265

8.6.2 Poly-3-hexylthiophene as a semiconducting polymer	265
8.6.3 Tantalum oxide as gate dielectric	266
8.6.4 Enzyme immobilization	267
8.6.5 Methodology	268
8.6.6 Results	269

Glossary	275
-----------------	------------

Index	293
--------------	------------