

edited by  
Ru-Shi Liu

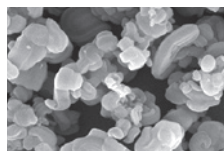
# CONTROLLED NANOFABRICATION

ADVANCES AND APPLICATIONS





# **CONTROLLED NANOFABRICATION**







edited by  
Ru-Shi Liu

# **CONTROLLED NANOFABRICATION**

ADVANCES AND APPLICATIONS

PAN STANFORD  PUBLISHING

*Published by*

Pan Stanford Publishing Pte. Ltd.  
Penthouse Level, Suntec Tower 3  
8 Temasek Boulevard  
Singapore 038988

Email: [editorial@panstanford.com](mailto:editorial@panstanford.com)

Web: [www.panstanford.com](http://www.panstanford.com)

### **British Library Cataloguing-in-Publication Data**

A catalogue record for this book is available from the British Library.

### **Controlled Nanofabrication: Advances and Applications**

Copyright © 2013 Pan Stanford Publishing Pte. Ltd.

*All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the publisher.*

For photocopying of material in this volume, please pay a copying fee through the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA. In this case permission to photocopy is not required from the publisher.

ISBN 978-981-4316-87-3 (Hardcover)

ISBN 978-981-4364-51-5 (eBook)

Printed in the USA

# Contents

<i>Preface</i>	xix
<b>1. An Introduction of Controlled Sizes and Shapes of Nanostructured Materials and Their Applications</b>	<b>1</b>
<i>Tai-Feng Hung and Ru-Shi Liu</i>	
1.1 Semiconductors	2
1.2 Hematite	5
1.3 Platinum	9
1.4 Conclusions	11
<b>2. Spatial Separation of Reaction Sites on Rutile TiO<sub>2</sub> Nanorod by Exposing Crystal Faces and Development of Visible Light Responsive Rutile TiO<sub>2</sub> Nanorod</b>	<b>17</b>
<i>Teruhisa Ohno and Naoya Murakami</i>	
2.1 Introduction	17
2.2 Morphology Controlled Rutile TiO <sub>2</sub> Nanorod with Exposed Crystal Faces	19
2.2.1 Experimental Details for Preparation and Activity Evaluation of Rutile TiO <sub>2</sub> Nanorod with Exposed Crystal Faces	20
2.2.2 Results and Discussion for Rutile TiO <sub>2</sub> Nanorod with Exposed Crystal Faces	21
2.3 Newly Exposed Crystal Face of Rutile TiO <sub>2</sub> Nanorod by Using Chemical-Etching Technique	25
2.3.1 Experimental Details for Preparation and Activity Evaluation of Chemically Etched Rutile TiO <sub>2</sub> Nanorod	25
2.3.2 Results and Discussion for Chemically Etched Rutile TiO <sub>2</sub> Nanorod	26
2.4 Visible-Light-Responsive Rutile TiO <sub>2</sub> Nanorod Without Etching Treatment Modified Selectively with Iron(III) ion Modification of Exposed Crystal Face	31

2.4.1	Experimental Details for Preparation and Activity Evaluation of Fe(III) Modified Rutile TiO <sub>2</sub> Nanorod	32
2.4.2	Results and Discussion for Visible-Light-Responsive Rutile TiO <sub>2</sub> Nanorod Modified with Fe(III) Ions	33
2.5	Conclusion	38
<b>3.</b>	<b>Controlled Shaping TiO<sub>2</sub> for Efficient Photocatalysis</b>	<b>43</b>
	<i>Gang Liu and Hui-Ming Cheng</i>	
3.1	Introduction	43
3.2	Predicted Non-Equilibrium Shapes of Anatase TiO <sub>2</sub>	47
3.2.1	Predicted Anatase TiO <sub>2</sub> with Dominant {010} Facets	47
3.2.2	Predicted Anatase TiO <sub>2</sub> with Dominant {001} Facets	48
3.3	Anatase TiO <sub>2</sub> Crystals with Dominant {101} Facets	50
3.3.1	Anatase TiO <sub>2</sub> Octahedra with Dominant {101} Facets	50
3.3.2	Anatase TiO <sub>2</sub> Belts with Dominant {101} Facets	53
3.4	Anatase TiO <sub>2</sub> Crystals with Dominant {001} Facets	54
3.4.1	Fluorine Induced a High Percentage of {001} Facets	54
3.4.2	Organic MCA Induced a High Percentage of {001} Facets	57
3.4.3	MCA-Free for a High Percentage of {001} Facets	57
3.4.4	Visible-Light-Responsive Anatase Crystals with Dominant {001} Facets	60
3.4.5	Anatase TiO <sub>2</sub> Crystals with a High Percentage of {010}	65
3.5	New Criteria to Determining Photocatalytic-Activity Order of Facets	67
<b>4.</b>	<b>Shape and Particle Size Controlled for Water Splitting</b>	<b>73</b>
	<i>Hao Ming Chen and Ru-Shi Liu</i>	
4.1	Introduction	73
4.1.1	Development of Water Splitting	73
4.1.2	Principle for Water Splitting	76
4.2	Band Engineering for Water Splitting	78



4.2.1	Bandgap and Water-Splitting Reaction	78
4.2.2	Size Effect on the Bandgap of the Sensitizer	81
4.3	Shape Effect on the Photoelectrochemical Electrode	83
4.3.1	Zero-Dimensional Nanostructure	83
4.3.2	One-Dimensional Nanostructure	85
4.3.2.1	Doping approach	85
4.3.2.2	Quantum dots sensitization	88
4.3.2.3	Composite structure	95
4.4	Conclusions and Future Prospects	97
<b>5.</b>	<b>Characterization of TiO<sub>2</sub> Nanoparticles Cytotoxicity</b>	<b>103</b>
	<i>Laurent Le Guyader and Chunying Chen</i>	
5.1	Introduction	103
5.1.1	What Are TiO <sub>2</sub> Nanoparticles?	103
5.1.2	TiO <sub>2</sub> Particles Applications	104
5.1.3	Toxicity Risks	105
5.2	Physiological Toxicity	106
5.2.1	Exposure	106
5.2.2	Lung (Inhalation, Intratracheal Instillation)	107
5.2.3	Skin (Dermal Exposure)	109
5.2.4	Central Nervous System (Nasal Instillation/ Inhalation)	110
5.2.5	Systemic Circulation (Intravenous and Intraarticular Exposure)	111
5.2.6	Liver, Kidneys, and Other Organs	112
5.2.7	Carcinogenesis	112
5.2.8	Conclusion	113
5.3	Cellular Toxicity	113
5.3.1	Introduction	113
5.3.2	Cellular Models	115
5.3.2.1	Lung models	115
5.3.2.2	Skin models	115
5.3.2.3	Immune system models	116
5.3.2.4	CNS models	117
5.3.3	Cytotoxic Responses	118
5.3.3.1	Oxidative stress	118
5.3.3.2	Protein oxidation	120
5.3.3.3	Lipid peroxidation	121

5.3.3.4	Lysosomal membrane disruption	121
5.3.3.5	Cathepsins	122
5.3.3.6	Pro-inflammatory mediators	122
5.3.3.7	Mitochondrial dysfunction	123
5.3.3.8	Caspases release	123
5.3.3.9	Genotoxicity	124
5.3.3.10	Apoptosis and necrosis	125
5.3.4	Phototoxicity	126
5.3.5	Conclusion	128
5.4	Discussion on the Parameters Influencing TiO <sub>2</sub> Toxicity	132
5.4.1	Introduction	132
5.4.2	Size Parameters	132
5.4.2.1	Agglomeration or aggregation of particles	133
5.4.2.2	Surface area	135
5.4.3	Concentration and Exposure Time	136
5.4.4	Shape	139
5.4.5	Crystal Phase	140
5.4.6	Uptake and Subcellular Localization	141
5.4.7	Cell Line	143
5.4.8	Surface Chemistry	145
5.5	Conclusion	146
<b>6.</b>	<b>Functionalized Porous Materials as Drug Carriers</b>	<b>155</b>
	<i>Jun Lin and Shanshan Huang</i>	
6.1	Introduction	155
6.2	Luminescence-Functionalized Mesoporous Silica Materials as Drug Carriers	157
6.3	Europium-Doped Mesoporous Hydroxyapatite and Bioactive Glass	163
6.3.1	Europium-Doped Mesoporous Hydroxyapatite	163
6.3.2	Europium-Doped Mesoporous Bioactive Glass	165
6.4	Self-Activated Luminescent Porous Materials	167
6.5	Upconversion-Functionalized Core-Shell Composites	169
6.6	Hollow Luminescent Porous Spheres as Smart Drug Carriers	173

6.7	Magnetic Mesoporous Silica Composites for Drug Delivery	174
6.8	Multifunctional Nanocomposites	176
6.9	Summary and Outlook	179
<b>7.</b>	<b>Shape and Size Selective Synthesis of Gold Nanostructures for Biomedical Applications</b>	<b>191</b>
	<i>Baginskiy Ivan and Ru-Shi Liu</i>	
7.1	Introduction	191
7.2	Sphere-Shaped Gold Nanostructures	196
7.2.1	Synthesis of Sphere-Shaped Core/Gold Shell Nanoparticles	196
7.2.1.1	Synthesis of monofunctional dielectric-core/gold-shell nanoparticles	197
7.2.1.2	Synthesis of multifunctional core/shell nanoparticles	201
7.2.2	Synthesis of Hollow Gold Nanoparticles	204
7.2.2.1	Synthesis of hollow gold nanoparticles by galvanic replacement reaction	205
7.2.2.2	Synthesis of hollow gold nanoparticles on inter-phase boundaries	207
7.3	Synthesis of One-Dimensional Gold Nanoparticles: Gold Nanorods	209
7.3.1	Seed-Mediated Growth of Gold Nanorods	209
7.3.2	Seedless Growth of Gold Nanorods	213
7.4	Three-Dimensional Gold Nanoparticles: Branched Gold Nanoparticles	216
7.5	Biological and Biomedical Applications	221
7.5.1	Surface Modification, Bioconjugation, Biocompatibility of GNPs	222
7.5.2	Photothermal Therapy of Cancer	226
7.5.3	Bioimaging Techniques Using Gold Nanoparticles	230
7.5.4	Application of Multifunctional Gold Nanoshells with Superparamagnetic Cores	234
7.6	Conclusion	236

<b>8. Shape-Controlled Synthesis of Nanocrystals and Their Facet-Dependent Properties</b>	<b>247</b>
<i>Michael H. Huang</i>	
8.1 Introduction	247
8.2 Nanocrystal Synthesis	249
8.2.1 Synthesis of Nanocrystals with Regular Polyhedral Structures	249
8.2.1.1 Metallic nanocrystals	249
8.2.1.2 Semiconductor nanocrystals	252
8.2.2 Insights of the Growth Mechanism from the Synthesis of Nanocrystals with Systematic Shape Evolution	258
8.3 Synthesis of Core–Shell Heterostructures	260
8.4 Synthesis of Hollow Nanostructures	265
8.5 Facet-Dependent Properties of Nanocrystals	268
8.6 Concluding Remarks	271
<b>9. Size- and Shape-Controlled Hybrid Inorganic Nanomaterials and Application for Low-Temperature CO Oxidation</b>	<b>279</b>
<i>Thanh-Dinh Nguyen and Trong-On Do</i>	
9.1 Introduction	280
9.2 Concepts in Surfactant-Assisted Synthesis of Multicomponent Nanohybrids	284
9.3 Types of Hybrid Inorganic Nanocrystals	286
9.3.1 Metal@Oxide	286
9.3.2 Metal@Semiconductor	294
9.3.3 Bimetallic Metal@Metal	300
9.4 Application of Nanohybrids as Nanocatalysts for CO Oxidation Reaction	305
9.5 Concluding Remarks	315
<b>10. Shape-Controlled Synthesis of Metal Oxide Nanocrystals</b>	<b>327</b>
<i>Cao Thang Dinh, Thanh Dinh Nguyen, Freddy Kleitz and Trong On Do</i>	
10.1 Introduction	328
10.2 Synthesis of Metal Oxide Nanocrystals	330

10.2.1	Hydrothermal/Solvothermal Methods	332
10.2.2	Two-Phase Routes	338
10.2.3	Thermal Decomposition	341
10.2.4	Microemulsions	345
10.3	Shape Control of Metal Oxide Colloidal Nanocrystals	348
10.3.1	Shape Control by Oriented Attachment	348
10.3.2	Shape Control by Surface Energy and Selective Adhesion	351
10.3.3	Shape Control by Control of the Growth Regime	353
10.3.4	Shape Control Using Dopants	355
10.3.5	Shape Control by a Confinement in an Inorganic Network	357
10.4	Summary	358
<b>11</b>	<b>Self-Assembly: A Novel Way to Fabricate Nanomaterials</b>	<b>369</b>
	<i>Zhiyong Tang and Zhening Zhu</i>	
11.1	Introduction	369
11.2	Strategies for Self-Assembly of Nanocrystals	370
11.2.1	Applying PSP Styles to the Document	371
11.2.2	Self-Assembly Using Templating Methods	372
11.2.3	Self-Assembly at Interfaces	374
11.2.4	Assisted Self-Assembly	375
11.3	Magnetically Responsive Self-Assembled Structures	377
11.4	Superlattices with Non-Spherical Building Blocks	379
11.4.1	Self-Assembly of Nanocubes	380
11.4.2	Self-Assembly of Nano-Octahedra	382
11.4.3	Self-Assembly of Nano-Rhombic Dodecahedral	384
11.5	DNA-Based Self-Assembly	387
<b>12</b>	<b>Shape-Controlled Synthesis of Platinum Nanostructures as Electrocatalyst for PEM Fuel Cell Applications</b>	<b>395</b>
	<i>Shuhui Sun and Xueliang Sun</i>	
12.1	Introduction	395
12.2	Shape-Controlled Synthesis of Pt Nanostructures	397
12.2.1	Zero-Dimensional (0D) Platinum Nanoparticles	399

12.2.1.1	Thermodynamic control	399
12.2.1.2	Reaction kinetics control	404
12.2.1.3	Electrochemical synthesis of unconventional shapes of Pt nanocrystals	404
12.2.2	One-Dimensional (1D) Platinum Nanowires/Nanorods and Nanotubes	406
12.2.2.1	Platinum nanowires/nanorods	407
12.2.2.2	Platinum nanotubes	421
12.2.3	Two-Dimensional (2D) Platinum Nanostructures	433
12.2.4	Three-Dimensional (3D) Platinum Nanostructures	435
12.2.4.1	Platinum nanodenrites and nanocages	435
12.2.4.2	Platinum multipods	437
12.3	Platinum-Based Nanostructures as Electrocatalysts for PEM Fuel Cells	439
12.3.1	Reaction Mechanisms for PEMFCs	439
12.3.2	Cathode Catalysts for ORR in DHFC	440
12.3.2.1	Comparison of the electrocatalytic performance of various Pt polyhedra and Pt/C toward ORR	440
12.3.2.2	Comparison of the electrocatalytic performance of supportless Pt nanotubes and Pt/C toward ORR	442
12.3.2.3	Comparison of the electrocatalytic performance of star-like Pt nanowires/C and Pt/C toward ORR	443
12.3.3	Anode Catalysts for MOR in DMFC	446
12.3.3.1	Comparison of the electrocatalytic performance of Pt nanowires/ TiO <sub>2</sub> and Pt/C toward MOR	446
12.3.3.2	Comparison of the electrocatalytic performance of Pt nanowires/ CNT@SnNW and Pt/C toward MOR	448
12.3.4	Anode Catalysts for FAOR in Direct Formic Acid Fuel Cell (DFAFC)	450

12.3.4.1	Comparison of the electrocatalytic performance of Pt tetrahexahedra, Pt nanospheres, and Pt/C toward formic acid oxidation	450
12.3.4.2	Comparison of the electrocatalytic performance of Pt multipods, Pt discs, and Pt hexagons toward formic acid oxidation	451
12.3.4.3	Comparison of the electrocatalytic performance of Pt Y-junction, Pt nanowires (NW), and Pt/C toward formic acid oxidation	453
12.4	Conclusions and Outlook	454
<b>13.</b>	<b>Controlled Particle Size and Shape of Nanomaterials and Their Applications in Supercapacitors</b>	<b>473</b>
	<i>Zubiao Wen, Shu Tian, Lili Liu and Yuping Wu</i>	
13.1	Introduction	473
13.2	Supercapacitors	476
13.3	Nano Anode Materials for Supercapacitors	478
13.3.1	Nanoporous Carbons	478
13.3.2	Carbon Nanofibers	481
13.3.3	Carbon Nanotubes	483
13.3.4	Nano Titanium Oxides	484
13.3.5	Electrochemical Performance of Nano Anode Materials	485
13.4	Nano Cathode Materials	491
13.4.1	Nano Ruthenium Oxides	492
13.4.2	Nano Manganese Dioxides	494
13.4.3	Nano Vanadium Pentoxides	495
13.4.4	Nano Conducting Polymers	497
13.4.4.1	Polyaniline	498
13.4.4.2	Polypyrrole	498
13.4.4.3	Thiophene-based CPs	499
13.4.4.4	Nanocomposites	499
13.4.5	Nano Intercalation Compounds	501
13.4.6	Electrochemical Performance of Nano Cathode Materials	502
13.5	Future Prospects	512

**14. Nano/Composite Materials for Lithium-ion Batteries 521***Shu-Lei Chou, Jia-Zhao Wang, Hua-Kun Liu and Shi-Xue Dou*

14.1	Introduction	521
14.1.1	General Background	521
14.1.2	Statement of Problem	522
14.1.2.1	Cathode materials	522
14.1.2.2	Anode materials	522
14.1.2.3	Electrolytes	523
14.1.3	Literature Review	523
14.1.3.1	Anode materials	525
14.1.3.2	Cathode Materials	529
14.2	Tin-Dioxide Nanomaterials and Carbon-Coated Tin-Dioxide Nanocomposite	534
14.2.1	Introduction	534
14.2.2	SnO <sub>2</sub> Nanotubes	536
14.2.2.1	Synthesis method	536
14.2.2.2	Physical and structural characterization	536
14.2.2.3	Formation mechanism	539
14.2.2.4	Electrochemical performance	540
14.2.3	Carbon-Coated SnO <sub>2</sub> Nanoparticles	545
14.2.3.1	Synthesis method	545
14.2.3.2	Physical and structural characterization	545
14.2.3.3	Electrochemical performance	547
14.2.4	Summary	553
14.3	High-Surface-Area, Hollow-Structured Alpha-Iron Oxide/Carbon Composite	553
14.3.1	Introduction	553
14.3.2	Experimental	554
14.3.2.1	Synthesis	554
14.3.2.2	Electrochemical characterizations	556
14.3.3	Structure and Morphologies	557
14.3.4	Electrochemical Characterization	561
14.3.5	Summary	569
14.4	Free-Standing Polypyrrole and Polypyrrole-Lithium Iron Phosphate Composite Films	569



14.4.1	Introduction	569
14.4.2	Experimental	570
14.4.2.1	Synthesis of free-standing polypyrrole film	570
14.4.2.2	Synthesis of free-standing polypyrrole-LiFePO <sub>4</sub> composite film	571
14.4.3	Free-Standing Polypyrrole Film	571
14.4.3.1	Physical and structural characterization	571
14.4.3.2	Electrochemical characterization	573
14.4.4	Polypyrrole-LiFePO <sub>4</sub> Composite Film	575
14.4.4.1	Physical and structural characterization	575
14.4.4.2	Electrochemical characterization	578
14.4.5	Summary	581
14.5	Lithium Battery Using Vanadium Oxide Nanomaterial Cathode and Room-Temperature Ionic Liquid Electrolyte	581
14.5.1	Introduction	581
14.5.2	Synthesis	583
14.5.3	Structure and Morphology Analysis	583
14.5.3.1	XRD and BET	583
14.5.3.2	SEM and TEM	585
14.5.4	Electrochemical Characterization	586
14.5.4.1	Charge and discharge curves	586
14.5.4.2	Possible reason for enhanced cycling stability	588
14.5.4.3	Cyclic voltammetry	592
14.5.4.4	Cycling stability	593
14.5.4.5	High-rate capability	594
14.5.4.6	Kinetics investigation	595
14.5.5	Summary	598
14.6	General Conclusions and Outlook	598
14.6.1	General Conclusions	598
14.6.1.1	Anode materials	598
14.6.1.2	Cathode materials	599
14.6.2	Outlook	600

## **15. Controlled Size and Shape of Graphene and Its Application in Li-ion Battery 623**

*Bei Wang, Ali Reza Ranjbartoreh and Guoxiu Wang*

15.1	Introduction	623
15.2	Properties of Graphene	624
15.2.1	Electrical Properties	624
15.2.2	Optical Properties	625
15.2.3	Thermal Properties	625
15.2.4	Microbiological Properties	625
15.2.5	Mechanical Properties	626
	15.2.5.1 Tension	626
	15.2.5.2 Hardness	626
	15.2.5.3 Bending	627
15.3	Preparation of Graphene	628
15.3.1	Mechanical Exfoliation	628
15.3.2	Epitaxial Growth	629
15.3.3	Intercalation	629
15.3.4	Chemical Vapour Deposition	629
15.3.5	Bacterial Reduction of Graphene Oxide	630
15.3.6	Chemical Method	630
	15.3.6.1 Chemical synthesis of organophilic graphene	631
15.3.7	Electrolytic Exfoliation	631
15.4	General Characterizations of Graphene	632
15.4.1	X-ray Diffraction	632
15.4.2	Field Emission Scanning Electronic Microscopy	633
15.4.3	Transmission Electronic Microscopy	634
15.4.4	Atomic Force Microscopy	635
15.4.5	Raman Spectroscopy and UV-Vis Spectroscopy	635
15.5	Applications in Li-ion Battery	637
15.5.1	Pure Graphene Nanosheets as Anode Material	637
15.5.2	Graphene-Based Composite for Lithium-ion Batteries	640
	15.5.2.1 Sn/graphene	640
	15.5.2.2 SnO <sub>2</sub> /graphene	646

15.5.2.3	Other examples	648
15.6	Conclusions	649
<b>16.</b>	<b>Controlled Growth of Quantum Dots and Their Application as Wavelength Converters for LEDs</b>	<b>657</b>
	<i>Byoung-Hwa Kwon, Dong Seon Jang, Hyunki Kim and Duk Young Jeon</i>	
16.1	Introduction	657
16.2	Synthesis of Quantum Dots	658
16.2.1	Basic Principles	659
16.2.1.1	Quantum size effect: transformation in density of states vs. size	659
16.2.1.2	Burst nucleation: the separation of nucleation and growth	662
16.2.1.3	Synthesis of monodisperse QDs with hot-injection method	666
16.2.2	Controlled Growth of Cd Chalcogenide QDs	667
16.2.3	Controlled Growth of Cd Chalcogenide Core/Shell QDs	670
16.3	Application of Quantum Dots as LED Wavelength Converters	673
16.3.1	Current Status of Application to QD-LEDs	674
16.3.1.1	White QD-LEDs for illumination	675
16.3.1.2	White QD-LEDs for display application	677
16.3.2	Toxicity	678
16.3.2.1	ZnSe QDs	678
16.3.2.2	InP QDs	680
16.3.2.3	Ternary structured QDs	681
16.3.3	Stability	682
16.3.3.1	Engineering of ligands: stable and effective ligands	683
16.3.3.2	Engineering of inorganic shell: QDs with thickshell or giant QDs	684
16.3.4	Encapsulation	687
16.3.4.1	Agglomeration	688
16.3.4.2	Polymerization hindrances	688
16.4	Conclusions and Outlook	689

<b>17. Artificial Nanostructures with Controlled Sizes and Shapes for Field Emission Displays</b>	<b>699</b>
<i>Chaoyang Li and Akimitsu Hatta</i>	
17.1 Zinc Oxide Nanostructure Fabrication	700
17.1.1 Fabrication of ZnO Thin Film by RF Magnetron Sputtering	701
17.1.2 ZnO Nanostructure Fabrication in Reducing Treatment Process	702
17.1.2.1 Effects of gas ratio	702
17.1.2.2 Effects of deposition pressure	705
17.1.2.3 Effects of annealing time	705
17.1.3 Applications	707
17.2 Diamond Nanostructures Fabrication	708
17.2.1 Formation of Diamond Nanowires	708
17.2.1.1 Fabrication process	708
17.2.1.2 Experimental procedures	709
17.2.2 Diamond Nanowires Formed Under Various Conditions	712
17.2.2.1 Effect of oxygen ratio	712
17.2.2.2 Effect of metal coating	713
17.2.2.3 Effect of etching time	715
17.2.3 Application of Diamond Nanostructures	716
17.2.3.1 Field emission measurement system in SEM	716
17.2.3.2 Future perspective of diamond nanostructure applications	716
17.3 Microscopic Silicon Needles Fabricated by Plasma Etching	717
<i>Index</i>	729

# Preface

Today, there is global consensus on the importance of nanotechnology. The major economies of the world depend on important areas of nanotechnology for science and technology development. When the size and the shape of materials are reduced to the nanoscale dimension, their physical and chemical properties can change dramatically. This book focuses on the controlled size and shape of nanostructured materials and their applications. The applications cover a broad field, especially energy-related uses. The book may be the first to clearly point out the relationship between the size and the structure of the materials, which strongly affects their properties. Understanding these control parameters has important technological implications for energy conversion and storage, biotechnology, lighting and display, and so forth.

The content is organized into 17 chapters. Chapter 1 introduces readers to the theme of the book. Chapters 2 to 5 present examples of crystal faces of  $\text{TiO}_2$  and  $\text{ZnO}$  and the effects of shaping on their photocatalysis and cytotoxicity. Chapter 6 is a review of functionalized porous materials as drug carriers. Chapters 7 and 8 focus on the shape- and size-selective synthesis of gold nanomaterials for biomedical and photocatalytic applications. Chapters 9 to 11 demonstrate the size- and shape-controlled self-assembly of hybrid inorganic nanomaterials and their application for low-temperature CO oxidation. Chapters 12 to 17 focus on the shape-controlled synthesis of nanostructured materials for application in fuel cells, supercapacitors, Li-ion batteries, light-emitting diodes, and field emission display.

I thank the authors, globally recognized in their fields, for their invaluable contributions, which have made this book comprehensive and a very useful reference for scientists and students.

**Ru-Shi Liu**

