Janos H. Fendler

# Nanoparticles and Nanostructured Films

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# Nanoparticles and Nanostructured Films

## Preparation, Characterization and Applications

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# Preface

Small is not only beautiful but also eminently useful. The virtues of working in the nanodomain are increasingly recognized by the scientific community, the technological world and even the popular press. The number of research publications in this area has been increasing exponentially. Additionally, national and international biological, physical, chemical, engineering, and materials science societies and government agencies have been organizing workshops, meetings, and symposia around some aspects of nanoparticle research with increasing frequency. This burgeoning interest is amply justified, of course, by the unique properties of nanoparticles and nanostructured materials and by the promise these systems hold as components of optical, electrical, electro-optical, magnetic, magneto-optical, and catalytic sensors and devices.

The appearance of numerous review articles and books on nanoparticle research has helped the neophyte to digest the veritable information overload. No recent overview has appeared, however, to the best of our knowledge, that focuses upon the utilization of "wet" chemical and colloid chemical methods for the preparation of nanoparticles and nanostructured films. The purpose of the present book is to fill this gap by summarizing current accomplishments in preparing and characterizing nanoparticles and nanostructured films and to point out their potential applications. Versatility, relative ease of preparation and transfer from the liquid to the solid phase, convenience of scale-up, and economy are the advantages of the chemical approach to advanced materials synthesis.

Electrochemistry has reached sufficient maturity and sophistication to be used for the layer-by-layer deposition of nanoparticles and nanoparticulate films. In Chapters 1 and 3 the state-of-the-art electrodeposition of quantum dots, superlattices, and nanocomposites is surveyed. Chemists have plenty to learn from mother nature. Much of the work on template-directed nanoparticle growth is inspired by biomineralization, the oriented growth of inorganic crystals in biomembranes. Advantage has been taken of organized surfactant assemblies that mimic the biological membranes to grow nanoparticles and nanoparticulate films. Chapters 2 and 4 highlight the growth of metallic, semiconducting, and magnetic nanoparticles under monolayers and within the confines of reverse micelles. More rigid templates have also been employed for nanoparticle preparations. This approach is illustrated for such diverse templates as opal (Chapter 13), nanoporous membranes (Chapter 10), and zeolites (Chapter 17). Chapter 7 emphasizes the use of block copolymer micelles as hosts for generating metallic nanoparticles.

The recent attention to porous silicon nanoparticles has been prompted by their demonstrated photoluminescence and electroluminescence, as well as by their promise to function as optical interconnects and chemically tunable sensors, which require passive surfaces that are stable to oxidation yet are able to conduct current efficiently. Chemical and plasma-induced silicon nanocluster formation and growth are examined in Chapters 5 and 8. The potentially important, albeit as yet unexplored fullerene nanoparticles and their two-dimensional crystal growth are surveyed in Chapter 6.

Nanoparticles themselves can be used as building blocks for two-dimensional arrays and/or three-dimensional networks. They can also be derivatized and treated as if they were simple molecules. This approach should lead to the type of hetero-supramolecular structures that are illustrated in Chapter 16. Such complex chemistries must go hand-in-hand with an improved understanding of surface and colloid chemical interactions. Some aspects of these are discussed in Chapters 11 and 12.

Exploitation of nanoparticles and nanostructured materials requires an appreciation of electron and photoelectron transfer mechanisms therein. Chapter 9 presents a well balanced view of the electron transfer processes in nanostructured semiconductor thin films while Chapter 14 discusses charge transfer at nanocrystalline metal, oxide–semiconductor interfaces and its relation to electrochromic–battery and photovoltaic–photocatalytic interfaces. Significantly, as summarized in Chapter 15, nanoparticles provide us with the possibility of monitoring, and ultimately exploiting, single electron transfer events.

An attempt has been made in the last chapter to provide the newcomer with handy "recipes" for the preparation of nanoparticles and nanostructured films as well as to summarize current accomplishments and future prospects in this intellectually fascinating and highly relevant area of research. Inevitably, current activities soon become "past achievements", and interested readers will have to acquaint themselves with the latest results as they appear in primary publications and as they are disseminated at scientific meetings. Chapter 18 also lists selected data on the properties of the most frequently used bulk semiconductors in order to permit much needed comparisons between the bulk and size-quantized materials.

I am grateful to all the contributing authors who took time from their busy schedule to write their chapters and thus to share their expertise with the scientific community. I also thank Dr. Peter Gregory and Dr. Jörn Ritterbusch, the Editors at WILEY-VCH, and their staff or initiating this project and for providing enthusiastic support throughout the various stages of publication.

October 1997 Janos H. Fendler

# Contents

List of Contributors XVII

**1 Electrodeposited Quantum Dots: Size Control by Semiconductor–Substrate Lattice Mismatch** **1**
*G. Hodes, Y. Golan, D. Behar, Y. Zhang, B. Alperson, and I. Rubinstein*
1.1 Introduction 1
1.2 The CdSe/Au System 3
1.3 Change of Semiconductor Lattice Spacing – Cd(Se, Te)/Au 5
1.4 Change of Substrate Lattice Spacing – CdSe/Pd 6
1.5 Thicker Layers of CdSe on Au and Pd 7
1.6 Other Semiconductor–Substrate Systems 8
1.6.1 (Cd, Zn)Se/Au 9
1.6.1.1 CDs/Au 10
1.6.1.2 CDs/Pd 12
1.6.1.3 CdSe/Au–Pd 13
1.7 Bandgap Measurements 16
1.8 Conclusion and Speculations 19
Acknowledgments 20
References 20

**2 Oriented Growth of Nanoparticles at Organized Assemblies** **23**
*F. C. Meldrum*
2.1 Introduction 23
2.2 Oriented Crystal Growth on Self-assembled Monolayers and Multilayers 25
2.2.1 Growth of Zincophosphate Zeolites on Zirconium Phosphate Multilayers 25
2.2.2 Oriented Aluminophosphate Zeolite Crystals Grown on Self-assembled Monolayers 25
2.2.3 Nucleation and Growth of Oriented Ceramic Films on Self-assembled Monolayers 26

2.3 Epitaxial Crystal Growth on Langmuir–Blodgett Films 27
2.4 Langmuir Monolayers as Templates for Epitaxial Crystal Growth 28
2.4.1 Epitaxial Growth of Semiconductor Nanoparticles under Langmuir Monolayers 28
2.4.2 Formation of PbS Crystals under Arachidic Acid (AA) and Octadecylamine (ODA) Monolayers 29
2.4.3 Investigation of PbS Physiochemical Properties as a Function of Crystal Morphology 32
2.4.4 Epitaxial Growth of Cadmium Sulfide Nanoparticles under Arachidic Acid Monolayers 33
2.4.5 Epitaxial Growth of PbSe Crystals under Arachidic Acid Monolayers 35
2.5 Sodium Chloride Growth under Monolayers 40
2.5.1 Ice Nucleation under Aliphatic Alcohol Monolayers 41
2.5.2 Kinetic Measurements of Ice Nucleation under Alcohol Monolayers 43
2.6 Biomineralization 44
2.6.1 Growth of Calcium Carbonate under Langmuir Monolayers 45
2.6.2 Epitaxial Growth of Barium Sulfate under Surfactant Monolayers 47
2.6.3 Oriented Nucleation of Gypsum ($CaSO_4 \cdot 2H_2O$) under Langmuir Monolayers 49
References 50

**3 Electrodeposition of Superlattices and Nanocomposites 53**
*J. A. Switzer*
3.1 Introduction 53
3.2 Electrodeposition of Inorganic Materials 54
3.2.1 Electrodeposition of Metal Chalcogenides 55
3.2.2 Electrodeposition of Metal Oxides 56
3.3 Electrodeposition of Nanophase Materials 57
3.3.1 Growth in Nanobeakers 57
3.3.2 Scanning Probe Nanolithography 57
3.3.3 Epitaxial Growth of Quantum Dots 58
3.3.4 Electrodeposition of Superlattices 58
3.4 Characterization of Superlattices 59
3.4.1 X-ray Diffraction 59
3.4.2 Scanning Probe Microscopy 61
3.5 *In Situ* Studies of Epitaxial Growth 62
3.6 Electrodeposition of Nanocomposites 63
3.7 The Future 67
Acknowledgments 67
References 68

**4 Size and Morphology Control of Nanoparticle Growth in Organized Surfactant Assemblies** **71**
*M. P. Pileni*
4.1 Introduction 71
4.2 Reverse Micelles 73
4.2.1 Syntheses and Optical Properties of Metallic Copper Particles 73
4.2.2 Syntheses and Optical Properties of Semiconductor Semimagnetic Quantum Dots 74
4.3 Oil in Water Micelles 77
4.3.1 Magnetic Fluids: Syntheses and Properties 78
4.3.2 Control of the Shape of Metallic Copper Particles 82
4.4 Interconnected Systems 84
4.5 Onion and Planar Lamellar Phases in Equilibrium 87
4.6 Spherulites 87
4.7 Self-organization of Nanoparticles in 2D and 3D Superlattices 90
4.7.1 Silver Sulfide, $(Ag_2S)n$, Self-assemblies 92
4.7.2 Self-assemblies Made with Silver Metallic Nanoparticles 94
4.8 Conclusions 98
Acknowledgments 98
References 98

**5 Synthesis of Silicon Nanoclusters** **101**
*R. A. Bley and S. M. Kauzlarich*
5.1 Introduction 101
5.2 Quantum Confinement 101
5.3 Development of Semiconductor Nanoclusters 103
5.3.1 Development of Silicon Nanoclusters 104
5.3.2 Crystalline Structure of Silicon 104
5.3.3 Band Structure of Silicon 105
5.4 Synthetic Methods of Silicon Nanocluster Production 107
5.4.1 Decomposition of Silanes 107
5.4.2 Silicon Nanoparticles from Porous Silicon 108
5.4.3 Solution Synthesis of Silicon Nanoparticles 108
5.5 Characterization 111
5.5.1 Infrared Spectroscopy 111
5.5.2 Electron Microscopy 112
5.5.3 Absorption Spectrum 113
5.5.4 Photoluminescence Spectroscopy 114
5.6 Summary 116
Acknowledgments 116
References 117

**6 Two-Dimensional Crystal Growth of Fullerenes and Nanoparticles** **119**
*D. M. Guldi*
6.1 Introduction 119

6.2 Pristine Fullerenes 120
6.2.1 Films of Pristine Fullerenes, $C_{60}$ and $C_{70}$ 120
6.2.2 Langmuir–Blodgett Films of Pristine Fullerenes, $C_{60}$ and $C_{70}$ 122
6.2.3 Langmuir–Blodgett Films of Pristine $C_{60}$/Amphiphilic Matrix Molecules 125
6.3 Langmuir–Blodgett Films of Functionalized Fullerene Derivatives 125
6.3.1 Mono-functionalized Fullerene Derivatives 126
6.3.2 Mono-functionalized Fullerene Derivatives Bearing Hydrophilic Groups 128
6.3.3 Multiply Functionalized Fullerene Derivatives 131
6.3.4 Transfer to Solid Substrates 132
6.4 Fullerenes Covalently Attached to Self-assembled, Monolayers and Self-assembled Monolayers of Functionalized Fullerene Derivatives 134
6.4.1 Self-assembled Monolayers of Fullerene Containing Supramolecular Dyads 136
6.4.2 Self-assembly of Functionalized Fullerene Derivatives via Electrostatic Interaction 136
6.5 Outlook and Application 137
Acknowledgment 138
References 138

**7 Metal Colloids in Block Copolymer Micelles: Formation and Material Properties 145**
*L. Bronstein, M. Antonietti, and P. Valetsky*
7.1 Introduction 145
7.2 Overview of Current Activities on Amphiphilic Block Copolymers as Tailored Protecting Systems for Colloids 146
7.3 Chemistry of Amphiphilic Block Copolymers and Their Aggregation Behavior; Loading of the Micelles and Binding inside the Micelles 148
7.3.1 Amphiphilic Block Copolymers 148
7.3.2 Aggregation Behavior of Amphiphilic Block Copolymer Micelles 150
7.3.3 Metal Salt Incorporation 151
7.4 Synthesis of Metal Colloids in the Presence of Amphiphilic Block Copolymers in Organic Solvents 153
7.4.1 Synthesis of Metal Colloids inside the Micellar Cores: The Nanoreactor Concept 153
7.4.2 Fast Homogeneous Reduction 154
7.4.3 Slow Homogeneous Reduction 155
7.4.4 Generation of the Metal Colloids with Heterogeneous Interface Reactions 156
7.4.5 Homogeneous Colloid Production and Heteroaggregation with Amphiphilic Copolymer Micelles 160
7.5 Synthesis of Metal Colloids in the Presence of Amphiphilic Block Copolymers in Water or Related Polar Solvents 162

7.5.1 Micelle Formation due to Hydrophobic/Hydrophilic Block Copolymers and Interaction of Metal Salts with the Hydrophilic Shell 162
7.5.2 Colloid Synthesis in "Double-Hydrophilic" Block Copolymers 163
7.6 Catalytic Properties of Metal Colloids Stabilized by Amphiphilic Copolymers 166
7.7 Magnetic Properties of Co-colloids Stabilized by Amphiphilic Block Copolymers 168
7.8 Conclusion and Outlook 169
References 170

**8 Plasma-Produced Silicon Nanoparticle Growth and Crystallization Process 173**
*J. Dutta, H. Hofmann, C. Hollenstein, and H. Hofmeister*
8.1 Introduction 173
8.2 Experimental Methods 174
8.2.1 Powder Preparation and Annealing 174
8.2.2 Transmission Electron Microscopy 175
8.2.3 Vibrational Spectroscopy 175
8.2.4 Plasma and *In Situ* Powder Diagnostics 175
8.3 Structure of the Silicon Nanoparticles 177
8.3.1 Morphology 177
8.3.2 Vibrational Spectroscopy 180
8.3.3 Infrared Spectra 180
8.3.4 Raman Spectra 181
8.4 Silicon Nanoparticle Synthesis and Related Properties 183
8.4.1 Powder Precursors 183
8.4.2 Powder Formation and Agglomeration 186
8.4.3 Powder Dynamics 189
8.4.4 *In Situ* Diagnostics of Powder Properties 189
8.5 Silicon Nanoparticle Processing 191
8.5.1 Crystallization 191
8.5.2 Sintering 195
8.5.3 Thermodynamics 195
8.5.4 Kinetics 199
8.6 Conclusions and Prospects 201
Acknowledgments 202
References 202

**9 Electron Transfer Processes in Nanostructured Semiconductor Thin Films 207**
*P. V. Kamat*
9.1 Introduction 207
9.2 Preparation and Characterization of Nanostructured Semiconductor Thin Films 208
9.2.1 From Colloidal Suspensions 209
9.2.2 Chemical Precipitation 210

9.2.3 Electrochemical Deposition 211
9.2.4 Self-assembled Layers 211
9.2.5 Surface Modification 211
9.3 Optical Properties 212
9.3.1 Electron Storage and Photochromic Effects 212
9.3.2 Photocurrent Generation 214
9.3.3 Sensitization of Large-Bandgap Semiconductors 216
9.3.4 Photocatalysis 217
9.4 Mechanism and Electron Transfer in Semiconductor Thin Films 219
9.4.1 Charge Injection from Excited Dye into Semiconductor nanoclusters 219
9.4.2 Kinetics of the Charge Injection Process 220
9.4.3 Modulation of Electron Transfer at the Semiconductor–Dye Interface 223
9.4.4 Back Electron Transfer 226
9.4.5 Charge Transport in Semiconductor Films 228
9.5 Conclusion 229
Acknowledgments 229
References 229

**10 Template Synthesis of Nanoparticles in Nanoporous Membranes** **235**
*J. C. Hulteen and C. R. Martin*
10.1 Introduction 235
10.2 Membranes Used 236
10.2.1 "Track-etch" 236
10.2.2 Porous Alumina 236
10.2.3 Other Nanoporous Materials 238
10.3 Template Synthetic Strategies 238
10.3.1 Electrochemical Deposition 238
10.3.2 Electroless Deposition 240
10.3.3 Chemical Polymerization 241
10.3.4 Sol-Gel Deposition 242
10.3.5 Chemical Vapor Deposition 242
10.4 Composite Nanostructures 244
10.5 Optical Properties of Gold Nanoparticles 247
10.5.1 Fabrication 247
10.5.2 Structural Characterization 248
10.5.3 Optical Characterization 249
10.6 Nanoelectrode Ensembles 250
10.6.1 Fabrication 250
10.6.2 Current Response of the NEE 251
10.6.3 Detection Limits 253
10.7 Metal Nanotube Membranes 254
10.7.1 Fabrication 255
10.7.2 Ion-Selective Membranes 255

10.8 Semiconductor Nanotubules and Nanofibers 257
10.8.1 Structural Characterization 257
10.8.2 Photocatalysis 258
10.9 Conclusion 259
Acknowledgements 260
References 260

**11 Morphology-Dependent Photocatalysis with Nanoparticle Aggregates 263**
*M. Tomkiewicz and S. Kelly*
11.1 Introduction 263
11.2 $TiO_2$ Aerogels 265
11.2.1 Morphology 265
11.2.2 Control 267
11.3 Evolution of Coordination Structure 267
11.3.1 Raman Scattering 267
11.4 Quantum Efficiencies 271
Acknowledgment 273
References 273

**12 Zeta Potential and Colloid Reaction Kinetics 275**
*P. Mulvaney*
12.1 Introduction 275
12.2 The EDL around Metal Oxides 276
12.2.1 The Helmholtz Region 276
12.2.2 The Diffuse Layer 279
12.2.3 The Diffuse Layer for Micron Sized Colloid Particles 280
12.2.4 The Diffuse Layer for Nanosized Particles 281
12.2.5 The ZOS Model for Poorly Defined Nanoparticles 282
12.2.6 The Point of Zero Charge and the Isoelectric Point 284
12.3 Colloid Electron Transfer Kinetics – Theory 285
12.3.1 Mass-Transfer-Limited Reactions 285
12.3.2 Activation-Controlled Electron Transfer 287
12.3.3 The Transition between Activation and Mass Transfer Limits 288
12.4 Colloid Kinetics – Experimental Data 289
12.4.1 The Effect of pH 289
12.4.2 The Effect of Electrolyte Concentration on Electron Transfer 290
12.4.3 The Effect of the Zeta Potential and Radical Charge on the Rate of Electron Transfer 291
12.4.4 Non-Nernstian Behavior 295
12.4.5 Extensions to Other Systems 296
12.5 The Effect of Zeta on Radical Scavenging Yields 296
12.6 Colloid Nucleation and Nanoparticle Stability 300
12.6.1 Some Unresolved Aspects of Colloid Redox Chemistry 302

Acknowledgments 304
References 305

**13 Semiconductor Nanoparticles in Three-Dimensional Matrices** **307**
*S. G. Romanov and C. M. Sotomayor-Torres*
13.1 Introduction 307
13.2 Material Issues 308
13.3 Optical Properties 312
13.4 Transport Properties 318
13.5 Prospects 331
Acknowledgements 331
References 331

**14 Charge Transfer at Nanocrystalline Metal-Oxide Semiconductor/Solution Interfaces: Mechanistic and Energetic Links between Electrochromic/ Battery Interfaces and Photovoltaic/Photocatalytic Interfaces** **335**
*B. I. Lemon, L. A. Lyon, and J. T. Hupp*
14.1 Introduction 335
14.2 Electrochromics 337
14.2.1 $V_2O_5$ 337
14.2.2 $MoO_3$ 338
14.2.3 $WO_3$ 339
14.3 Photovoltaics 340
14.3.1 General Observations 340
14.3.2 $TiO_2$ 340
14.3.3 $SnO_2$ 343
14.3.4 ZnO 344
14.4 Energetic Considerations 344
14.4.1 Potentials 344
14.4.2 Reactivity Implications 346
14.5 Conclusions 346
Acknowledgment 347
References 347

**15 Nanoparticle-Mediated Monoelectron Conductivity** **349**
*S. Carrara*
15.1 Introduction 349
15.2 Historical Review 350
15.2.1 Single Charge Phenomena 350
15.2.2 The Theory 352
15.2.3 Experimental Results 353
15.2.4 Technological Applications 355
15.3 Monoelectron Conductivity 356
15.3.1 Semiclassical models 356
15.3.2 Electrostatic Considerations 358
15.3.3 Current in a Monoelectron System 360

15.4 Nanoparticle-Mediated Monoelectron Conductivity 362
15.4.1 Nanoparticles as Traps 363
15.4.2 Electrical Capacitance of a Nanoparticle 364
15.4.3 The Role of Nanoparticle Size 365
15.5 Conclusions 367
References 368

**16 Heterosupramolecular Chemistry** **371**
*X. Marguerettaz, L. Cusack, and D. Fitzmaurice*
16.1 Introduction 371
16.2 Heterosupermolecules 371
16.2.1 Covalent Assembly of a Heterosupermolecule 372
16.2.2 Noncovalent Self-assembly of a Heterosupermolecule 374
16.2.3 Heterosupermolecules – Are They Necessary? 377
16.3 Heterosupramolecular Assemblies 378
16.3.1 Covalent Heterosupramolecular Assemblies 378
16.3.2 Noncovalent Heterosupramoelecular Assemblies 381
16.3.3 Heterosupramolecular Assemblies – What Do We Gain? 384
16.4 Heterosupramolecular Chemistry and Molecular-Scale Devices 385
References 387

**17 Nanoclusters in Zeolites** **389**
*J. B. Nagy, I. Hannus, and I. Kiricsi*
17.1 Introduction 389
17.2 Synthesis of Nanoparticles in Zeolite Hosts 390
17.2.1 Description of Some Common Zeolite Structures 390
17.2.2 Synthesis of Metal Particles and Ionic Clusters in Zeolites 393
17.3 Characterization of Nanoparticles in Zeolite Hosts 398
17.3.1 Silver and Silver Halide Zeolites 400
17.3.2 Alkali Metal and Ionic Clusters in Zeolites 405
17.3.3 Transition Metal Clusters in Zeolites 413
17.3.4 Miscellaneous 418
17.3.4.1 New Forms of Luminescent Silicon 418
17.3.4.2 Semiconductor Nanoclusters in Zeolites 420
17.3.4.3 Quantum Chains 422
17.3.4.4 Microporous Semiconductors 423
17.4 Prospects 424
Acknowledgments 425
References 425

**18 Nanoparticles and Nanostructured Films: Current Accomplishments and Future Prospects** **429**
*J. H. Fendler, Y. Tian*
18.1 Introduction 429
18.2 Preparations of Nanoparticles and Nanostructured Films: Current State of the Art 430

18.2.1 Definitions 430
18.2.2 Chemical Preparations of Nanoparticles 431
18.2.3 Preparation of Composite Nanoparticles, Nanoparticle Arrays, and Nanostructured Films 441
18.3 Properties of Bulk Semiconductors and Semiconductor Nanoparticles Compared and Contrasted 449
18.4 Current Trends and Future Directions 454
Acknowledgments 456
References 456

**Index** **463**

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