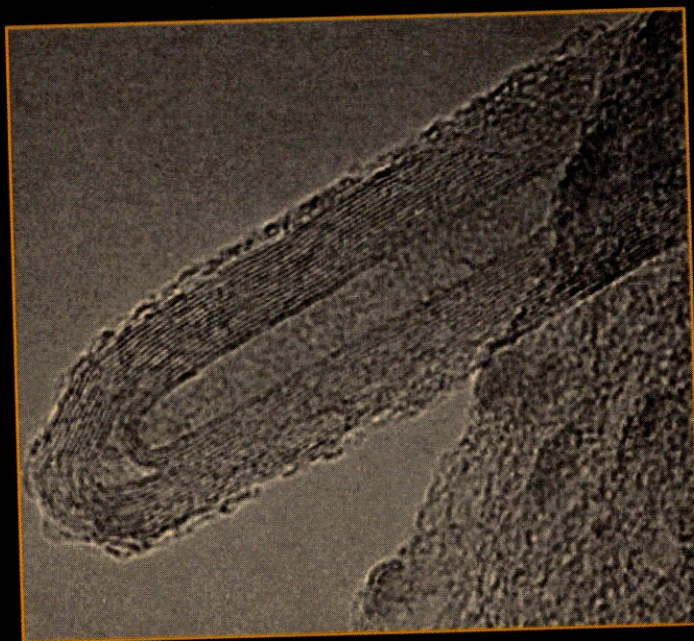


NANOSTRUCTURE SCIENCE AND TECHNOLOGY
Series Editor: David J. Lockwood

*Functional
Nanostructures
Processing, Characterization,
and Applications*



Edited by
Sudipta Seal

Contents

Preface.....	xiii
1. Advanced Ceramics and Nanocomposites of Half-metallic Ferromagnetic CrO₂ for Magnetic, GMR and Optical Sensors.....	1
<i>S. Ram, S. Biswas, and H. J-Fecht</i>	
1. Introduction	1
1.1. Definition of Half-metals and Half-metallic Compounds	1
1.2. Spin Polarization	5
2. Chromium Dioxide Ceramics and Nanocomposites	6
2.1. Crystal Structure	6
2.2. Methods of Synthesis	7
3. Stability and Controlled Transformation—in Phase-stabilized Particles	21
4. Electronic Band Structure	24
5. Electronic Properties	27
5.1. Dielectric Properties	27
5.2. Electrical Properties	30
6. Magnetic Properties	37
7. GMR Properties	42
8. Optical Properties	48
9. Applications	52
10. Toxicities and Hazards	52
Acknowledgment	53
References	53
Questions	63
2. Functional Nanostructured Thin Films.....	65
<i>Hare Krishna and Ramki Kalyanaraman</i>	
1. Introduction	65

1.1. Fabricating Nanostructured Surfaces	67
1.2. Self-assembly of Nanostructures by Film Nucleation and Growth	69
1.3. Self-assembly by Ion Irradiation	77
1.4. Characterization	81
1.5. Applications	93
1.6. Conclusion	100
Acknowledgment	101
References	101
Questions	106
3. MEMS for Nanotechnology: Top-down Perspective	107
<i>Chanashyam Londe, Arum Han, Hyoung J. Cho</i>	
1. Introduction	107
2. Micromachining Techniques	108
2.1. Photolithography	108
2.2. Bulk Micromachining	110
2.3. Surface Micromachining	113
2.4. Combined Method	115
3. Nanofabrication	117
3.1. Electron Beam Lithography (EBL)	119
3.2. Scanning Probe Lithography (SPL)	124
3.3. Soft Lithography	126
3.4. Nanoimprint Lithography (NIL)	128
4. Integration and Interface	131
4.1. Carbon Nanotube (CNT) Manipulation—with Microelectrode	131
4.2. Nanoparticle Interface with Microelectrode	132
5. Applications	134
5.1. Nanobeam	134
5.2. Nanoprobe	138
5.3. Nanopore and Nanogap	141
5.4. Channel and Needle	143
5.5. Nanowire and Nanotube	147
5.6. Nanocrystal and Nanorescent	154
5.7. Tools for Nanoscale Manipulation	155
6. Conclusion	158
Acknowledgment	160
References	160
Questions	167
4. Nanostructured Biomaterials	168
<i>Samar J. Kalita</i>	
1. Introduction	168
1.1. Biocompatibility and Types of Tissue Responses	172
2. Classification	173
2.1. Metallic Biomaterials	173
2.2. Ceramic Biomaterials	181
2.3. Polymeric Biomaterials	196
2.4. Composite Biomaterials	202
3. Cell Response to Nanobiomaterials and Current Advances	204
4. Summary	208
References	210
Questions	219
5. Self-Assembly in Nanophase Separated Polymer and Thin Film: Supramolecular Assembly	220
<i>Naba K. Dutta and Nannita Roy Choudhury</i>	
1. Introduction	220
1.1. Self-assembly	220
1.2. Strategies of Self-assembling Supramolecular Complexes	223
2. Mesophase Separation in Block Co-Polymer System	228
2.1. Evolution of Supramolecular Assembly in Block Copolymers	228
2.2. Synthetic Strategy of Multiblock Copolymers	240
2.3. Nanophase Separation in Side Chain Crystalline Polymers	248
3. Self-Assembled Nanoparticle System	253
3.1. Zero-dimensional Self-assembly	253
3.2. Nanoparticles in Nanostructured Polymer	258
3.3. Two-dimensional Thin Film	261
3.4. Self-assembly in Biocompatible System and Biomolecular Assembly	270
3.5. Supramolecular Assembly via Hydrogen Bonding	272
3.6. Molecular Clusters	276
4. Characterization of a Self-assembled System	277
4.1. Advanced Scattering Techniques	278
4.2. Advanced Surface Analysis Techniques	282
4.3. MALDI-MS, TOF-SIMS	283

4.5. Solid-state NMR in Characterizing Self-assembled Nanostructures.....	286
4.6. Advanced Thermal Analysis.....	287
5. Application and Future Outlook.....	289
6. Acknowledgment.....	291
References.....	291
Questions.....	304
6. Nanostructures: Sensor and Catalytic Properties.....	305
<i>B. Roldan Cuenya, A. Kolmakov</i>	
1. Introduction.....	305
1.1. Overview.....	305
1.2. Why are Nanostructures Important for Gas Sensing and Catalysis? (Structure-Sensitivity Relationship).....	307
1.3. The Impact on the Fundamental Science.....	309
2. Phenomena at Nanoscaled Metal and Semiconducting Oxide Surfaces Relevant to Gas Sensing and Catalysis.....	309
2.1. Pristine Oxide Surfaces: Physisorption vs. Chemisorption.....	309
2.2. Band Bending and Charge Depletion.....	311
2.3. Chemisorption and Magnetization.....	313
3. Nanostructured Gas Sensors: Some Examples of Detection Principles.....	315
3.1. Two-dimensional Nanoscaled Metal/Oxide/Semiconductor Diodes.....	315
3.2. Quasi-1D Nanostructured Oxides as a New Platform for Gas Sensing.....	323
4. New Surface Science Trends for the Characterization of Nanostructures.....	331
5. Concluding Remarks.....	334
Acknowledgment.....	335
References.....	335
Questions.....	344
7. Nanostructured High-Anisotropy Materials for High-Density Magnetic Recording.....	345
<i>J. S. Chen, C. J. Sun, G. M. Chow</i>	
1. Introduction.....	345
2. Definition and Characterization of Chemical Ordering of $L1_0$ FePt.....	349
2.2. Characterization of $L1_0$ FePt Chemical Ordering.....	351
3. Preparation of $L1_0$ FePt Films and Parameters Affecting the Chemical Ordering.....	356
3.1. Preparation of $L1_0$ FePt Films.....	356
3.2. Effects of Temperature, Stoichiometry and Film Thickness on Chemical Ordering.....	356
3.3. Promotion of Chemical Ordering by Doping.....	358
3.4. Strain- or Stress-Induced $L1_0$ Ordering.....	360
3.5. Other Approaches to Enhance $L1_0$ Ordering.....	368
4. Intrinsic Properties of the $L1_0$ FePt Films.....	369
4.1. Magnetocrystalline Anisotropy, Magnetization and Curie Temperature of $L1_0$ FePt Films.....	369
4.2. Effects of Size and Interface on Coercivity and Magnetization Reversal.....	374
5. Application of $L1_0$ FePt alloy thin film for perpendicular magnetic recording.....	378
5.1. Control of FePt (001) Texture.....	379
5.2. Control of Exchange Coupling and Grain Size of FePt Films.....	386
5.3. Recording Performance of $L1_0$ FePt Perpendicular Media.....	398
6. Summary and Outlook.....	405
References.....	405
8. High-Resolution Transmission Electron Microscopy for Nanocharacterization.....	414
<i>Helge Heinrich</i>	
1. Introduction.....	414
2. Sample Preparation.....	416
2.1. Electropolishing.....	418
2.2. Ion-beam Milling.....	419
2.3. The Focused Ion-beam Technique.....	419
2.4. Tripod Polishing.....	421
2.5. Powders and Suspensions.....	422
3. Principles of Image Formation.....	423
3.1. The Transmission Electron Microscope.....	424
3.2. The Ewald Construction and the Reciprocal Space.....	433
3.3. Scattering Theory.....	452
4. Imaging of Nanostructured Material.....	458
4.1. High-resolution Transmission Electron Microscopy (HRTEM).....	458

4.2. Scanning Transmission Electron Microscopy	470
4.3. Electron Holography	477
5. Analytical Electron Microscopy	482
5.1. Electron Energy-loss Spectroscopy	485
5.2. Energy-filtered Electron Microscopy	488
5.3. X-ray Analysis and Chemical Mapping	490
6. New Developments in Electron Microscopy	493
7. Acknowledgments	494
References	494
Questions	500
Solutions to Questions	502
9. Applications of Atomic Force Microscope (AFM) in the Field of Nanomaterials and Nanocomposites	504
<i>S. Bandyopadhyay, S. K. Samudrala, A. K. Bhowmick, and S. K. Gupta</i>	
1. Introduction	504
1.1. Nanomaterials	505
1.2. Nanocomposites	508
1.3. Characterization Techniques	509
2. Atomic Force Microscope Instrumentation and Setup	512
2.1. Principle of Operation	513
2.2. Factors that Influence the Precision and Accuracy of AFM Imaging	515
2.3. Different Modes of Imaging in AFM	517
2.4. Constant Force and Constant Height Criterion	520
2.5. AFM in Nanotechnological Applications	520
3. Contributions of AFM to the Field of Nanotechnology	521
3.1. Characterization of Nanoparticles/Nanomaterials	521
3.2. Characterization of Nanocomposites	526
3.3. Conductive AFM as a Means to Characterize Electrical Properties	538
3.4. Characterization of Nano-Mechanical and Nano-Tribological Properties	540
3.5. Nanofabrication/Nanolithography	550
4. Concluding Remarks	557
Acknowledgments	557
References	558
Questions	568
Index	569