
Contents – Volume X

27	Gecko Feet: Natural Attachment Systems for Smart Adhesion— Mechanism, Modeling, and Development of Bio-Inspired Materials	
	<i>Bharat Bhushan, Robert A. Sayer</i>	1
27.1	Introduction	1
27.2	Tokay Gecko	2
27.2.1	Construction of Tokay Gecko	2
27.2.2	Other Attachment Systems	5
27.2.3	Adaptation to Surface Roughness	7
27.2.4	Peeling	8
27.2.5	Self-Cleaning	10
27.3	Attachment Mechanisms	12
27.3.1	Van der Waals Forces	12
27.3.2	Capillary Forces	13
27.4	Experimental Adhesion Test Techniques and Data	14
27.4.1	Adhesion Under Ambient Conditions	15
27.4.2	Effects of Temperature	17
27.4.3	Effects of Humidity	18
27.4.4	Effects of Hydrophobicity	18
27.5	Adhesion Modeling	19
27.5.1	Spring Model	21
27.5.2	Single Spring Contact Analysis	21
27.5.3	The Multilevel Hierarchical Spring Analysis	23
27.5.4	Adhesion Results for the Gecko Attachment System Contacting a Rough Surface	26
27.5.5	Capillarity Effects	30
27.5.6	Adhesion Results that Account for Capillarity Effects	31
27.6	Modeling of Biomimetic Fibrillar Structures	34
27.6.1	Fiber Model	34
27.6.2	Single Fiber Contact Analysis	34
27.6.3	Constraints	35
27.6.4	Numerical Simulation	39
27.6.5	Results and Discussion	41

27.7	Fabrication of Biomimetic Gecko Skin	48
27.7.1	Single-Level Hierarchical Structures	49
27.7.2	Multilevel Hierarchical Structures	53
27.8	Closure	55
	Appendix	56
	References	59
28	Carrier Transport in Advanced Semiconductor Materials	
	<i>Filippo Giannazzo, Patrick Fiorenza, Vito Raineri</i>	63
28.1	Majority Carrier Distribution in Semiconductors: Imaging and Quantification	64
28.1.1	Basic Principles of SCM	64
28.1.2	Carrier Imaging Capability by SCM	67
28.1.3	Quantification of SCM Raw Data	70
28.1.4	Basic Principles of SSRM	78
28.1.5	Carrier Imaging Capability by SSRM	81
28.1.6	Quantification of SSRM Raw Data	81
28.1.7	Drift Mobility by SCM and SSRM	85
28.2	Carrier Transport Through Metal–Semiconductor Barriers by C-AFM	88
28.3	Charge Transport in Dielectrics by C-AFM	93
28.3.1	Direct Determination of Breakdown	97
28.3.2	Weibull Statistics by C-AFM	99
28.4	Conclusion	101
	References	101
29	Visualization of Fixed Charges Stored in Condensed Matter and Its Application to Memory Technology	
	<i>Yasuo Cho</i>	105
29.1	Introduction	105
29.2	Principle and Theory for SNDM	106
29.3	Microscopic Observation of Area Distribution of the Ferroelectric Domain Using SNDM	107
29.4	Visualization of Stored Charge in Semiconductor Flash Memories Using SNDM	109
29.5	Higher-Order SNDM	110
29.6	Noncontact SNDM	111
29.7	SNDM for 3D Observation of Nanoscale Ferroelectric Domains . .	112

29.8	Next-Generation Ultra-High-Density Ferroelectric Data Storage Based on SNDM	114
29.8.1	Overview of Ferroelectric Data Storage	114
29.8.2	SNDM Nanodomain Engineering System and Ferroelectric Recording Medium	116
29.8.3	Nanodomain Formation in a LiTaO ₃ Single Crystal	117
29.8.4	High-Speed Switching of Nanoscale Ferroelectric Domains in Congruent Single-Crystal LiTaO ₃	120
29.8.5	Prototype of a High-Density Ferroelectric Data Storage System	122
29.8.6	Realization of 10 Tbit/in. ² Memory Density	126
29.9	Outlook	128
	References	129

30 Applications of Scanning Probe Methods in Chemical Mechanical Planarization

	<i>Toshi Kasai, Bharat Bhushan</i>	131
30.1	Overview of CMP Technology and the Need for SPM	131
30.1.1	CMP Technology and Its Key Elements	131
30.1.2	Various CMP Processes and the Need for SPM	134
30.2	AFP for the Evaluation of Dishing and Erosion	137
30.3	Surface Planarization and Roughness Characterization in CMP Using AFM	141
30.4	Use of Modified Atomic Force Microscope Tips for Fundamental Studies of CMP Mechanisms	144
30.5	Conclusions	149
	References	149

31 Scanning Probe Microscope Application for Single Molecules in a π -Conjugated Polymer Toward Molecular Devices Based on Polymer Chemistry

	<i>Ken-ichi Shinohara</i>	153
31.1	Introduction	153
31.2	Chiral Helical π -Conjugated Polymer	154
31.2.1	Helical Chirality of a π -Conjugated Main Chain Induced by Polymerization of Phenylacetylene with Chiral Bulky Groups	156
31.2.2	Direct Measurement of the Chiral Quaternary Structure in a π -Conjugated Polymer	158
31.2.3	Direct Measurement of Structural Diversity in Single Molecules of a Chiral Helical π -Conjugated Polymer	163

31.2.4	Dynamic Structure of Single Molecules in a Chiral Helical π -Conjugated Polymer by a High-Speed AFM	166
31.3	Supramolecular Chiral π -Conjugated Polymer	169
31.3.1	Simultaneous Imaging of Structure and Fluorescence of a Supramolecular Chiral π -Conjugated Polymer	169
31.3.2	Dynamic Structure of a Supramolecular Chiral π -Conjugated Polymer by a High-Speed AFM	177
	References	181
32	Scanning Probe Microscopy on Polymer Solar Cells <i>Joachim Loos, Alexander Alexeev</i>	183
32.1	Brief Introduction to Polymer Solar Cells	184
32.2	Sample Preparation and Characterization Techniques	188
32.3	Morphology Features of the Photoactive Layer	190
32.3.1	Influence of Composition and Solvents on the Morphology of the Active Layer	190
32.3.2	Influence of Annealing	193
32.3.3	All-Polymer Solar Cells	199
32.4	Nanoscale Characterization of Properties of the Active Layer . . .	201
32.4.1	Local Optical Properties As Measured by Scanning Near-Field Optical Microscopy	201
32.4.2	Characterization of Nanoscale Electrical Properties	203
32.5	Summary and Outlook	212
	References	213
33	Scanning Probe Anodization for Nanopatterning <i>Hiroyuki Sugimura</i>	217
33.1	Introduction	217
33.2	Electrochemical Origin of SPM-Based Local Oxidation	218
33.3	Variation in Scanning Probe Anodization	223
33.3.1	Patternable Materials in Scanning Probe Anodization	223
33.3.2	Environment Control in Scanning Probe Anodization	226
33.3.3	Electrochemical Scanning Surface Modification Using Cathodic Reactions	229
33.4	Progress in Scanning Probe Anodization	232
33.4.1	From STM-Based Anodization to AFM-Based Anodization	232
33.4.2	Versatility of AFM-Based Scanning Probe Anodization	233
33.4.3	In Situ Characterization of Anodized Structures by AFM-Based Methods	233

33.4.4	Technical Development of Scanning Probe Anodization	237
33.5	Lithographic Applications of Scanning Probe Anodization	239
33.5.1	Device Prototyping	239
33.5.2	Pattern Transfer from Anodic Oxide to Other Materials	240
33.5.3	Integration of Scanning Probe Lithography with Other High-Throughput Lithographies	247
33.5.4	Chemical Manipulation of Nano-objects by the Use of a Nanotemplate Prepared by Scanning Probe Anodization	248
33.6	Conclusion	251
	References	251

34 Tissue Engineering: Nanoscale Contacts in Cell Adhesion to Substrates

*Mario D’Acunto, Paolo Giusti, Franco Maria Montevecchi,
Gianluca Ciardelli*

257

34.1	Tissue Engineering: A Brief Introduction	257
34.2	Fundamental Features of Cell Motility and Cell–Substrates Adhesion	261
34.2.1	Biomimetic Scaffolds, Roughness, and Contact Guidance for Cell Adhesion and Motility	268
34.3	Experimental Strategies for Cell–ECM Adhesion Force Measurements	271
34.4	Conclusions	279
34.5	Glossary	279
	References	280

35 Scanning Probe Microscopy in Biological Research

Tatsuo Ushiki, Kazushige Kawabata

285

35.1	Introduction	285
35.2	SPM for Visualization of the Surface of Biomaterials	286
35.2.1	Advantages of AFM in Biological Studies	286
35.2.2	AFM of Biomolecules	287
35.2.3	AFM of Isolated Intracellular and Extracellular Structures	289
35.2.4	AFM of Tissue Sections	292
35.2.5	AFM of Living Cells and Their Movement	292
35.2.6	Combination of AFM with Scanning Near-Field Optical Microscopy for Imaging Biomaterials	294
35.3	SPM for Measuring Physical Properties of Biomaterials	296
35.3.1	Evaluation Methods of Viscoelasticity	296
35.3.2	Examples for Viscoelasticity Mapping Measurements	299

35.3.3	Combination of Viscoelasticity Measurement with Other Techniques	302
35.4	SPM as a Manipulation Tool in Biology	304
35.5	Conclusion	306
	References	306
36	Novel Nanoindentation Techniques and Their Applications	
	<i>Jiping Ye</i>	309
36.1	Introduction	309
36.2	Basic Principles of Contact	311
36.2.1	Meyer's Law	311
36.2.2	Elastic Contact Solution.	312
36.3	Tip Rigidity and Geometry	313
36.4	Hardness and Modulus Measurements	314
36.4.1	Analysis Method	314
36.4.2	Practical Application Aspects	316
36.4.3	Recent Applications	320
36.5	Yield Stress and Modulus Measurements	324
36.5.1	Analysis Method	324
36.5.2	Recent Applications	326
36.6	Work-Hardening Rate and Exponent Measurements	329
36.6.1	Analysis Method	329
36.6.2	Practical Application Aspects.	333
36.6.3	Recent Applications	335
36.7	Viscoelastic Compliance and Modulus	336
36.7.1	Analysis Method	336
36.7.2	Practical Application Aspects.	339
36.8	Other Mechanical Characteristics	342
36.9	Outlook	343
	References	343
37	Applications to Nano-Dispersion Macromolecule Material Evaluation in an Electrophotographic Printer	
	<i>Yasushi Kadota</i>	347
37.1	Introduction	347
37.2	Electrophotographic Processes	348
37.2.1	Principle and Characteristics of an Electrophotographic System	348

37.2.2	Microcharacteristic and Analysis Technology for Functional Components	349
37.3	SPM Applications to Electrophotographic Systems	352
37.3.1	Measurement of Electrostatic Charge of Toner	352
37.3.2	Measurement of the Adhesive Force Between a Particle and a Substrate	353
37.3.3	Observation of a Nanodispersion Macromolecule Interface —Toner Adhesion to a Fusing Roller	355
37.4	Current Technology Subjects	357
	References	357

38 Automated AFM as an Industrial Process Metrology Tool for Nanoelectronic Manufacturing

	<i>Tianming Bao, David Fong, Sean Hand</i>	359
38.1	Introduction	359
38.2	Dimensional Metrology with AFM	361
38.2.1	Dimensional Metrology	361
38.2.2	AFM Scanning Technology	362
38.2.3	AFM Probe Technology	367
38.2.4	AFM Metrology Capability	367
38.3	Applications in Semiconductors— Logic and Memory Integrated Circuits	370
38.3.1	Shallow Trench Isolation Resist Pattern	370
38.3.2	STI Etch	372
38.3.3	STI CMP	375
38.3.4	Gate Resist Pattern	378
38.3.5	Gate Etch	379
38.3.6	FinFET Gate Formation	383
38.3.7	Gate Sidewall Spacer	385
38.3.8	Strained SiGe Source/Drain Recess	385
38.3.9	Pre-metal Dielectric CMP	386
38.3.10	Contact and Via Photo Pattern	387
38.3.11	Contact Etch	387
38.3.12	Contact CMP	389
38.3.13	Metal Trench Photo Pattern	390
38.3.14	Metal Trench Etch	390
38.3.15	Via Etch	392
38.3.16	Via Etch	394
38.3.17	Roughness	396
38.3.18	LWR, LER, and SWR	397
38.3.19	DRAM DT Capacitor	397
38.3.20	Ferroelectric RAM Capacitor	398
38.3.21	Optical Proximity Correction	398

38.4	Applications in Photomask	399
38.4.1	Photomask Pattern and Etch	399
38.4.2	Photomask Defect Review and Repair	400
38.5	Applications in Hard Disk Manufacturing	401
38.5.1	Magnetic Thin-Film Recording Head	401
38.5.2	Slider for Hard Drive	405
38.6	Applications in Microelectromechanical System Devices	406
38.6.1	Contact Image Sensor	406
38.6.2	Digital Light Processor Mirror Device	408
38.7	Challenge and Potential Improvement	408
38.8	Conclusion	409
	References	411
	Subject Index	413

Applied Scanning Probe Methods X
Biomimetics and Industrial Applications
Bhushan, B.; Fuchs, H.; Tomitori, M. (Eds.)
2008, LIX, 427 p., Hardcover
ISBN: 978-3-540-74084-1