
Contents

1 Science and Technology in the Twenty-First Century	
<i>Seizo Morita</i>	1
1.1 Trend of Science and Technology in the Twenty-First Century	1
1.2 Previous Prospect in SPM Roadmap 2000 and the State-of-the-Art	3
1.3 SPM Roadmap	4
1.3.1 Roadmap from Both Sides of Seeds and Needs	4
1.3.2 Various Directions of SPM Roadmap	5
References	6
2 Scanning Tunneling Microscopy	
<i>Masahiko Tomitori</i>	7
2.1 Basic Principle of Scanning Tunneling Microscopy	7
2.2 History of STM	10
2.3 Present States and Unsettled Issues	12
2.4 Roadmap	13
2.4.1 Further STM Combination with Other Microscopies and Spectroscopies	13
2.4.2 Miniaturized, Multi-, and Intelligent STM	13
2.4.3 Well-Defined Tips and Hybrid Tips	14
2.4.4 Evolution of STM Utilizing Phase of Tunneling Electron and Ballistic Electron	14
References	14
3 Atomic Force Microscopy	
<i>Yasuhiro Sugawara</i>	15
3.1 Principle	15
3.2 History	18
3.3 Present Situation and Issues	19
3.4 Roadmap	20
3.4.1 Development of New Force Spectroscopy	20

VIII Contents

3.4.2	Development of AFM Imaging Operating in Special Environments	20
3.4.3	Development of Imaging Method Under the Surface	21
	References	21

4 Near-Field Scanning Optical Microscope

	<i>Toshiharu Saiki</i>	23
4.1	Principle of NSOM	23
4.2	Progress in Fundamental Performance of NSOM	24
4.3	Current State of NSOM	26
4.3.1	Probe	26
4.3.2	Operation Environment	26
4.3.3	Near-Field Optical Spectroscopy	27
4.4	Roadmap	28
4.4.1	Enhancement of Spatial Resolution	28
4.4.2	Functional Probes	29
4.4.3	Extension of NSOM Operation Wavelength	30
4.4.4	Nanoscale Light–Matter Interaction	31
	References	32

5 Scanning Capacitance Microscope

	<i>Yoshitsugu Nakagawa</i>	35
5.1	Principle of SCM	35
5.2	Practical Dopant Profiling by SCM	37
5.3	Other SPMs for Dopant Profiling	39
5.4	Roadmap	40
	References	42

6 Electrostatic Force Microscopy

	<i>Masakazu Nakamura and Hirofumi Yamada</i>	43
6.1	Fundamentals	43
6.2	Present State and Problems	46
6.3	Roadmap	49
	References	51

7 Magnetic Force Microscope

	<i>Sumio Hosaka</i>	53
7.1	Principle of MFM [1, 2]	53
7.1.1	Estimated Resolution of MFM	53
7.1.2	Detectable Sensitivity of MFM	55
7.2	History of MFM	57
7.3	MFM Applications to Magnetic Recording Media	57
7.3.1	Observation of Ultrahigh Density Perpendicular Magnetic Recording	57
7.3.2	Evaluation of Recording Property in High Density Magnetic Recording	58

7.4	Roadmap of MFM	59
	References	61
8 STM-Induced Photon Emission Spectroscopy		
	<i>Tooru Murashita</i>	63
8.1	Characteristics	63
8.2	Emission Mechanism	64
	8.2.1 Electron–Hole Recombination Radiation	64
	8.2.2 Surface Plasmon Emission	65
8.3	History of Research and Development	66
8.4	Present Situation and Issues	66
8.5	Roadmap	67
	8.5.1 Equipment Performance	67
	8.5.2 Applications	69
	References	70
9 Scanning Atom Probe		
	<i>Osamu Nishikawa</i>	71
9.1	What is the Scanning Atom Probe?	71
9.2	Mass Analysis of Nonmetallic Specimens by the SAP	72
9.3	Present State and Problems	74
9.4	Roadmap	75
	References	76
10 Chemical Discrimination of Atoms and Molecules		
	<i>Komeda Tadahiro, Seizo Morita and Yauhiro Sugawara</i>	77
10.1	Recognition of Atom and Molecules; Inelastic Tunneling Spectroscopy	77
10.2	Chemical Identification of Atoms by AFM	79
	10.2.1 Chemical Identification of Atom Species by AFM	79
10.3	Roadmap	82
	10.3.1 Recognition of Atom and Molecules; Inelastic Tunneling Spectroscopy	82
	10.3.2 Future Prospect of Chemical Identification of Atoms by AFM	82
	References	83
11 Manipulation of Atoms and Molecules		
	<i>Tadahiro Komeda, Seizo Morita, Shukichi Tanaka and Hirofumi Yamada</i>	85
11.1	Manipulation of Atoms and Molecules: With the Use of STM Through Vibrational Excitation of Molecules	85
11.2	Manipulation of Atoms and Molecules by AFM	87
	11.2.1 Atom Manipulation by AFM	87
	11.2.2 AFM Manipulation of Organic Molecules	89
11.3	Roadmap	92

11.3.1	Manipulation of Atoms and Molecules: with the Use of STM Electrons	92
11.3.2	Future Prospect of Atom Manipulation by AFM.....	92
11.3.3	Future Prospect of AFM Manipulation of Organic Molecules	93
	References	94
12 Multiprobe SPM		
	<i>Shuji Hasegawa</i>	95
12.1	Present Status	95
12.1.1	Improvements	97
12.1.2	Roadmap	98
	References	99
13 AFM Measurement in Liquid		
	<i>Hirofumi Yamada</i>	101
13.1	Demand for AFM Imaging in Liquid	101
13.2	Dynamic Mode AFM Imaging in Liquid	102
13.2.1	AM-AFM and Q -Control Method	102
13.2.2	High-Resolution Imaging by FM-AFM	103
13.3	Technical Issues.....	105
13.3.1	Force Sensitivity Improvement	105
13.3.2	Spurious Peaks in Oscillation Spectrum	105
13.3.3	High-Resolution Imaging of a Sample Having Large Height Variations.....	106
13.4	Roadmap	106
13.4.1	High-Speed FM-AFM Imaging	106
13.4.2	Charge Density Mapping in Liquid	106
13.4.3	Mapping of Three-Dimensional Solvation Structure	107
	References	108
14 High-Speed SPM		
	<i>Toshio Ando</i>	109
14.1	Optimization of AFM Devices for High-Speed Scanning.....	109
14.1.1	Scanner and Related Devices.....	110
14.1.2	Cantilevers and Related Devices.....	110
14.1.3	Feedback Control and Related Techniques	111
14.2	World Trends in the High-Speed SPM	112
14.3	Roadmap	114
14.3.1	Until 2010	114
14.3.2	Until 2015	114
14.3.3	After 2015	115
	References	115

15 Scanning Nonlinear Dielectric Microscope	
<i>Yasuo Cho</i>	117
15.1 Principle and Theory for SNDM	117
15.2 Microscopic Observation of Area Distribution of Ferroelectric Domain Using SNDM	118
15.3 Visualization of Stored Charge in Semiconductors Using SNDM...	120
15.4 SNDM Ferroelectric Probe Memory	121
15.5 Roadmap	121
References	122
16 SPM Coupled with External Fields	
<i>Ken Nakajima and Tadahiro Komeda</i>	123
16.1 Light-Illumination STM	123
16.2 Coupling with Outer Field; Electron Spin Resonance Detection using STM	124
16.3 Roadmap	127
References	127
17 Probe Technology	
<i>Masamichi Yoshimura</i>	129
17.1 Introduction	129
17.2 Carbon Nanotube Probe	130
17.2.1 Mechanical Method	130
17.3 Roadmap	132
References	132
18 Characterization of Semiconducting Materials	
<i>Shuji Hasegawa and Masahiko Tomitori</i>	133
18.1 Characterization of Semiconductor Surfaces	133
18.2 Characterization of Semiconductor Interfaces	135
18.3 Characterization and Manipulation of Semiconductor Nanostructures	135
18.4 Characterization of Defects in Semiconductors	136
18.5 Characterization of Semiconductor Processes	137
References	137
19 Evaluation of SPM for LSI Devices	
<i>Koji Usuda, Takashi Furukawa and Yasushi Kadota</i>	139
19.1 LSI Devices and Forecast	139
19.1.1 Development of Si-LSI Devices	139
19.1.2 Forecast of Si-LSI Devices	140
19.2 Present Evaluation Technologies of LSI Devices and Latest Trend of SPM Characterization	141
19.2.1 LSI Device Evaluation Technology	142
19.2.2 Latest Trend of SPM Evaluations	142
19.2.3 New Evaluation with Advanced SPM Technology	146

19.3 Roadmap	147
References	149
20 SPM Characterization of Catalysts	
<i>Hiroshi Onishi</i>	151
20.1 SPM for What?	151
20.2 Roadmap	152
References	153
21 SPM Characterization of Biomaterials	
<i>Atsushi Ikai and Rehana Afrin</i>	155
21.1 Bioscience	155
21.1.1 Present Status of Nanoprobetechnology in Bioscience	155
21.1.2 Roadmap 2000	156
21.2 Biotechnology	158
21.2.1 Nanoprobetechnology in Biotechnology	158
21.3 Roadmap	160
21.3.1 Nanoprobetechnology in Biological Field	160
21.3.2 Bionanotechnology	164
References	165
22 SPM Characterization of Organic and Polymeric Materials	
<i>Shukichi Tanaka and Ken Nakajima</i>	167
22.1 Characterization of Organic Materials	167
22.2 Characterization of Polymeric Materials	171
22.3 Roadmap	174
References	174
23 Theories of SPM	
<i>Masaru Tsukada and Shin-ya Hasegawa</i>	177
23.1 Present Status of Theories of STM	177
23.2 Present Status of the Theory for AFM	178
23.3 Development of SPM Simulator	179
23.3.1 Hierarchical Tip and Sample Model	181
23.3.2 STM Simulation for the Decorated Tip	181
23.3.3 Theoretical Simulation Method for the Dynamic AFM in Liquid	182
23.3.4 SPM Simulation for Organic and Protein Molecules	182
23.3.5 The KFM Simulator	183
23.4 Present Status and Problems with Theories and Simulations of NSOM	183
23.5 Roadmap	186
References	188

24 When Will SPM Realize Our Dreams?

The Roadmap of SPM

Osamu Kubo 189

Index 197