

Contents

1	Introduction	1
	S. Sadewasser and Th. Glatzel	
	References	3
Part I Technical Aspects		
2	Experimental Technique and Working Modes	7
	S. Sadewasser	
2.1	Introduction	7
2.2	Non-Contact Atomic Force Microscopy	8
2.3	Kelvin Probe Force Microscopy	12
2.4	AM-KPFM	14
2.5	FM-KPFM	15
2.6	Comparison of AM- and FM-KPFM	16
2.7	Technical Realization	19
2.8	Other Modes and Additional Experimental Options.....	20
2.9	Additional Remarks	22
	References	24
3	Capacitive Crosstalk in AM-Mode KPFM	25
	H. Diesinger, D. Deresmes, and T. Mélin	
3.1	Introduction	25
3.2	AM-KPFM in Ultrahigh Vacuum.....	26
3.2.1	Self-Oscillating AFM Configuration	26
3.2.2	Electrostatic Excitation Dependence on dc Bias	28
3.2.3	Measurement of the Crosstalk	29
3.2.4	Active Compensation at the Cantilever Frequency	31
3.2.5	Crosstalk Reduction by Filtering	33
3.2.6	PLL Controlled AFM Setup	34
3.2.7	Comparison of the Countermeasures in UHV KPFM	35

3.3	AM-KPFM in Air	35
3.3.1	Crosstalk Determination by Resonance Curve Fitting	35
3.3.2	Crosstalk Compensation	38
3.4	Crosstalk Effect on Complementary Measurements.....	38
3.4.1	V_{dc} Sweep of the Oscillation Amplitude.....	39
3.4.2	Phase Dependent KPFM Reading	41
3.5	Comparison of Crosstalk Compensation in Vacuum and in Air ...	43
	References.....	43
4	The Effect of the Measuring Tip and Image Reconstruction	45
	Y. Rosenwaks, G. Elias, E. Strassbourg, A. Schwarzman, and A. Boag	
4.1	Introduction.....	45
4.2	Tip–Sample Electrostatic Interaction: A Review	46
4.2.1	Conducting Surfaces.....	46
4.2.2	Semiconducting Surfaces	49
4.3	Deconvolution and Image Restoration	52
4.3.1	Accurate Algorithm for Image Restoration	52
4.3.2	Tip Oscillation and the Effect of the Cantilever.....	56
4.3.3	The Effect of Nano Scale Tip Protrusions	59
4.3.4	Comparison with Experimental Results	63
4.4	Summary and Conclusions	66
	References.....	67
5	Contribution of the Numerical Approach to Kelvin Probe Force Microscopy on the Atomic-Scale	69
	L. Nony, F. Bocquet, A. Foster, and Ch. Loppacher	
5.1	Atomic-Scale Contrast in KPFM: Relevance of the Numerical Approach	69
5.2	Prerequisite: The nc-AFM Simulator.....	73
5.2.1	Overview of the Numerical Implementation	75
5.2.2	Numerical Schemes	76
5.2.3	Main Results	80
5.3	Numerical Implementation of the KPFM Methods: The nc-AFM/KPFM Simulator	80
5.3.1	Amplitude-Modulation KPFM (AM-KPFM)	81
5.3.2	Frequency Modulation KPFM (FM-KPFM)	84
5.3.3	Methodology with the nc-AFM/KPFM Simulator	85
5.4	Atomistic Simulations of Bias Voltage-Dependent Force Fields.....	87
5.4.1	Madelung Surface Potential of an Alkali Halide	87
5.4.2	Atomistic Simulations of the Bias Voltage-Dependent Force Field	88
5.5	Results with the nc-AFM/KPFM Simulator	92
5.5.1	Spectroscopic Curves.....	92
5.5.2	Topography and LCPD Images	93

5.6	Conclusions and Outlook	94
	References	95

Part II Selected Applications

6	Electronic Surface Properties of Semiconductor Surfaces and Interfaces	101
	R. Shikler	
6.1	Introduction	101
6.2	KPFM Measurements of <i>pn</i> Junctions	105
6.3	KPFM Measurements of Thin Film Solar Cells, the Role of Grain Boundaries	109
6.4	KPFM Measurements on Organic Materials	111
6.5	Concluding Remarks	113
	References	114
7	Surface Properties of Nanostructures Supported on Semiconductor Substrates	117
	F. Krok, J. Konior, and M. Szymonski	
7.1	Introduction	117
7.2	Experimental	118
7.3	Self-Assembling on Semiconductor Surfaces	120
7.3.1	Epitaxial Au Nanostructures Assembled on InSb(00 1)	120
7.3.2	Semiconductor Nanostructures Grown on Lattice-Mismatched Semiconductor Substrates	124
7.4	Surface Modification and Nanostructuring Induced by Laser Ablation and Ion Beams	127
7.5	Dielectric Structures Grown on InSb(00 1)	131
7.5.1	Accuracy of KPFM Signal Measurements	133
7.5.2	Theoretical Model of Electrostatic Tip-Sample Interaction	135
7.5.3	Numerical Simulation of KPFM Contrast	140
7.6	High Resolution KPFM Measurements	142
7.6.1	Limits of Lateral Resolution in FM-KPFM	142
7.6.2	Characterization of the Short-Range Bias Dependent Interactions: Quasispectroscopic KPFM Measurements	144
7.7	Summary	147
	References	148
8	Optoelectronic Studies of Solar Cells	151
	S. Sadewasser	
8.1	Introduction to Solar Cells	151
8.2	Nanometer Optoelectronic Surface Studies	154
8.2.1	Cu(In,Ga)(S,Se) ₂ -Based Solar Cells	154
8.2.2	Organic Solar Cells	159

8.3	Grain Boundaries in Thin Film Solar Cells	160
8.3.1	Si-Based Solar Cells	160
8.3.2	Cu(In,Ga)(S,Se) ₂ -Based Solar Cells	161
8.3.3	CdTe-Based Solar Cells	164
8.4	Cross-Sectional Device Characterization	165
8.4.1	Si-Based Solar Cells	165
8.4.2	Cu(In,Ga)(S,Se) ₂ -Based Solar Cells	166
8.4.3	III-V-Based Solar Cells	170
8.5	Summary.....	171
	References.....	171
9	Electrostatic Force Microscopy Characterization of Low Dimensional Systems	175
	Yoichi Miyahara, Lynda Cockins, and Peter Grütter	
9.1	Fluctuations of the Electrostatic Potential in Semiconductor Low-Dimensional Structures	175
9.1.1	Kelvin Probe Force Microscopy on Semiconductor Heterostructures	177
9.1.2	Large Spatial Fluctuations in Electrostatic Potential on Epitaxially Grown InAs/InGaAs/InP Heterostructures Observed by FM-AFM	178
9.2	Temporal Fluctuations of the Surface Potential Under Light Illumination	187
9.3	Single-Electron Sensitive Electrostatic Force Microscopy/Spectroscopy	189
9.3.1	Single-Electron Electrostatic Force Microscopy/Spectroscopy on Quantum Dots	189
9.3.2	Single-Electron Tunneling Force Microscopy/Spectroscopy on Insulator Surfaces.....	192
9.4	Related Scanning Probe Techniques	192
9.4.1	Scanning Single Electron Transistor Microscopy	192
9.4.2	Scanning Charge Accumulation Microscopy	194
9.5	Conclusion.....	194
	References.....	195
10	Local Work Function of Catalysts and Photoelectrodes	201
	H. Onishi and A. Sasahara	
10.1	Introduction.....	201
10.2	Na Adatoms	203
10.3	Cl Adatoms	205
10.4	Pt Adatoms and Particles	207
10.5	Ni Particles	212
10.6	Organometallic Dye	212
10.7	Summary and Perspectives	217
	References.....	218

11 Electronic Properties of Metal/Organic Interfaces	221
Christian Loppacher	
11.1 Introduction	221
11.1.1 Ohmic Contact	223
11.1.2 Schottky–Mott Contact	223
11.1.3 Dipole Formation at Interface	223
11.1.4 Macroscopic Methods	224
11.1.5 Nanoscopic Methods: Kelvin Probe Force Microscopy	226
11.2 Macroscopic Studies	226
11.3 Nanoscopic Studies	228
11.3.1 Quantitative Results by KPFM	228
11.3.2 Orientational Dependence	231
11.3.3 Dependence on Molecular Arrangement	234
11.4 Conclusion	237
References	238
12 KPFM and PFM of Biological Systems	243
B.J. Rodriguez and S.V. Kalinin	
12.1 Introduction	244
12.1.1 Electric Potentials and Electromechanics in Biosystems	244
12.1.2 Voltage Modulation SPM for Electrical and Electromechanical Measurements	246
12.2 KPFM of Biosystems	250
12.2.1 Organic Molecules	251
12.2.2 Biomolecular Systems	251
12.3 PFM of Biosystems	263
12.3.1 Historical Background	263
12.3.2 PFM of Collagen	265
12.3.3 PFM of Other Biosystems	267
12.3.4 Challenges	269
12.4 Liquid Imaging	270
12.4.1 Measurements of Electric Potential in Solution	270
12.4.2 Piezoresponse Force Microscopy	273
12.4.3 At the Intersection of Electrostatics and Electromechanics	279
12.5 Summary and Outlook	282
References	282
13 Measuring Atomic-Scale Variations of the Electrostatic Force	289
Th. Glatzel	
13.1 Introduction	289
13.2 Concept of the Local Work Function	290
13.2.1 Mesoscopic Measurements of the Work Function	292
13.2.2 Molecular Variations of the Local Contact Potential Difference	295

13.3	Measurements at the Atomic Scale	300
13.3.1	The Silicon(111)-(7 × 7) Surface	300
13.3.2	III–V Semiconductors	305
13.3.3	Rutile TiO ₂	307
13.3.4	Ionic Surfaces	311
13.3.5	KPFM by Tuning-Fork AFM	313
13.4	Influence of Measurement Parameters	317
13.4.1	Influence of the Tunneling Current	317
13.4.2	Influences by V_{ac}	319
13.4.3	The Influence of Short-Range Forces	322
13.4.4	Capacitive Crosstalk	323
13.5	Summary	324
	References	325
Index	329

Kelvin Probe Force Microscopy

Measuring and Compensating Electrostatic Forces

Sadewasser, S.; Glatzel, T. (Eds.)

2012, XIV, 334 p., Hardcover

ISBN: 978-3-642-22565-9