
Contents

1	Introduction	1
1.1	Motivation	1
1.2	Literature	2
1.3	Objective	3
2	Ferroelectrics	5
2.1	Fundamentals	5
2.2	Piezoelectric Effect	9
2.3	Electrostrictive Effect	11
2.4	Kay-Dunn Law	12
2.5	Properties	13
2.5.1	Barium Titanate	13
2.5.2	Potassium Niobate	14
2.5.3	Lead Titanate	14
2.5.4	Lead Zirconate Titanate	14
3	Finite Element Simulations	15
3.1	Linear Piezoelectric Equations	16
3.1.1	Relations between the mechanical coefficients	17
3.1.2	Relations between piezoelectric coefficients	18
3.2	Implementation	18
4	X-Ray Photoelectron Spectroscopy	21
4.1	XPS Principle	21
4.2	Contamination	22
4.3	Adsorbates	24
5	Scanning Probe Microscopy	25
5.1	Scanning Force Microscopy	25
5.1.1	Atomic Force Microscopy	25

5.1.2	Optical Lever Arm Method	26
5.1.3	Cantilever Properties	29
5.2	Piezoresponse Force Microscopy	32
5.2.1	Amplitude and Phase	33
5.2.2	In-plane and Out-of-plane Response	36
5.2.3	Multichannel Measurements	37
5.2.4	Potential Distribution	38
5.2.5	Distortion Factor	40
5.3	Cantilever Stiffness	42
5.4	Domain Engineering	42
6	Sample Preparation	45
6.1	Chemical Solution Deposition	45
6.1.1	Highly Diluted Solutions	46
6.1.2	Lead Titanate	46
6.1.3	Lead Zirconate Titanate	46
6.2	Template Controlled Deposition	47
6.3	Embedded Nanostructures	49
6.4	Pulsed Laser Deposition	50
7	Results and Discussion	53
7.1	Adsorbates on Ferroelectric Perovskites	53
7.1.1	Barium Titanate	55
7.1.2	Potassium Niobate	58
7.1.3	UHV Piezoresponse Force Microscopy	64
7.2	Optical Amplification	65
7.2.1	Geometrical Considerations	66
7.2.2	Measurements	68
7.3	In-plane Piezoresponse on Axially Symmetric Samples	70
7.3.1	Topography	71
7.3.2	Tip Asymmetry	71

7.3.3	Local Variation of Material Parameters	72
7.3.4	Additional Contributions	74
7.4	Shape Effects	75
7.4.1	Simulation	76
7.4.2	Measurement	80
7.4.3	Analysis	81
7.5	Mechanical Crosstalk	83
7.5.1	Analysis	84
7.5.2	Measurement	84
7.6	System Crosstalk	88
8	Summary	91
9	Outlook	93
	References	95
	Acknowledgements	107