

Contents

1	Introduction	1
1.1	RF Filters in GHz Wireless Applications	1
1.1.1	The Requirement of RF Filters	1
1.1.2	Types of RF Filters	2
1.2	Bulk Acoustic Wave (BAW) Resonator and Its Development	5
1.2.1	BAW Resonator	5
1.2.2	Micro Electromechanical Systems (MEMS) Applied in BAW	6
1.3	The Principle and Configurations of FBAR	7
1.3.1	The Principle of FBAR	7
1.3.2	Typical FBAR Configurations	8
1.3.3	Current Status of FBAR Filters	10
1.4	The Application of FBAR in Mass Loading Sensors	11
1.4.1	Acoustic Resonant Mass Sensors	11
1.4.2	FBAR Mass Loading Sensors	12
1.5	Overview of the Chapters	13
	References	13
2	Propagation of Acoustic Wave in Crystals	15
2.1	The Equation of Acoustic Plane Wave	16
2.1.1	The Equation of Elastic Deformation	16
2.1.2	Christoffel Equation	17
2.2	Propagation of Plane Wave in Isotropic Medium	19
2.3	Propagation of Plane Wave in Anisotropic Medium	20
2.3.1	Dispersion Relation and Inverse Velocity Face	20
2.3.2	The Solution of Wave Equation in Cubic Crystal	21
2.4	Piezoelectrically Active Wave Propagation	24
2.5	The Plane Wave Propagating in Piezoelectric Hexagonal Crystal	26
	References	29

3 The Theory of FBAR	31
3.1 The Electric Impedance of the Ideal FBAR	31
3.1.1 The Analytic Expression of the Electric Impedance	31
3.1.2 The Resonance of FBAR	34
3.2 The Electric Impedance of the Compound FBAR	36
3.2.1 The Definition of the Acoustic Impedance	36
3.2.2 The Boundary Condition of Compound FBAR	36
3.3 The Loss and Performances of FBAR	38
3.4 The Equivalent Electromechanical Mode of FBAR	39
3.4.1 The Equivalent Mode of the Layers	39
3.4.2 The Universal Equivalent Mode of FBAR	43
3.4.3 The Equivalent Circuit Nears the Resonance of FBAR	45
3.5 The Calculated Influence of the Materials and Structure on the Device Performance	47
3.5.1 The Effects of the Electrode	47
3.5.2 The Influences of Supporting Layer and the Residue Silicon Layer	48
References	50
4 The Deposition and Etching of AlN Film	51
4.1 Deposition of AlN Film by RF Magnetron Sputtering	51
4.1.1 Introduction	51
4.1.2 Experimental	52
4.1.3 The Effect of RF Power on the Film Texture	52
4.1.4 The Influence of Ambit Pressure and the Ratio of N ₂ /Ar on the Film Structure	53
4.1.5 The Influence of the Substrate Temperature on the Film Texture	54
4.1.6 The Microstructure and Chemical Component	55
4.2 The Structural Characteristics of AlN Films Deposited on Different Electrodes	56
4.3 Dry Etching of AlN Films Using Fluoride Plasma	57
4.3.1 The Dry Etching of AlN Films	57
4.3.2 Experimental	58
4.3.3 The Etching Rate	59
4.3.4 The Morphologies	60
4.3.5 The Etching Mechanism	61
4.4 The Wet Etching of AlN	62
4.4.1 The Wet Etching Process	62
4.4.2 Experimental	63
4.4.3 The Influence of the Film Texture	63
4.4.4 The Effects of Crystal Quality	65
References	68

5 The FBAR with Membrane Structure	71
5.1 The Structure and Testing Method	71
5.1.1 The Structure of the Device	71
5.1.2 The Testing Method	72
5.2 The Fabrication of Membrane Structured FBAR	73
5.3 The Preparation and Properties of PZT Film	75
5.3.1 Preparation of PZT Film Using Sol-Gel Method.....	75
5.3.2 The Structure and Properties of PZT Film.....	76
5.4 The Etching Process of the Films	77
5.4.1 The Etching of PZT Film.....	77
5.4.2 The Etching of SiO ₂	78
5.4.3 The Etching of Si	78
5.5 The Testing Results	78
References	80
6 Solidly Mounted Acoustic Resonator	81
6.1 The Design of SMR	81
6.1.1 The Structure of SMR	81
6.1.2 The Theory of the SMR	82
6.1.3 The Simulation of Frequency Response for SMR.....	85
6.2 The Preparation of SMR	87
6.2.1 The Bragg Reflector	87
6.2.2 The Fabrication of SMR	87
6.2.3 The Textures and Morphologies of the AlN Films	89
6.2.4 The Stress of Multilayer Film	91
6.3 Performance Test of SMR	92
6.3.1 The Parameter S11 of SMR	92
6.3.2 Impedance Characteristics of SMR	93
References	95
7 The Applications of FBAR in RF Filters	97
7.1 The Topology of the FBAR Filters	98
7.2 The Design of FBAR Filters	99
7.2.1 The Working Principle of FBAR Filters	99
7.2.2 The Design of the FBAR Filters	100
7.2.3 The Acoustic Coupled FBAR Filter	102
7.3 The Example of a FBAR Filter for PCS CDMA	103
7.4 The Duplexer and Oscillator Based on FBAR	105
7.4.1 Duplexer Based on the FBAR	105
7.4.2 The Oscillator Based on FBAR	106
7.4.3 The Integration of FBAR in RFIC	106
References	108
8 The FBAR Excited by Lateral Filed	109
8.1 Introduction	110
8.1.1 Two Kinds of Excitation Mode in Piezoelectric Resonator...	110
8.1.2 Lateral Filed Excitation FBARs.....	111

8.2	Theoretical Backgrounds	112
8.2.1	The Excitation and Thickness Shear Mode Wave Propagation.....	112
8.2.2	Electric Characteristics of LFE Resonators	115
8.3	LFE FBAR Fabrication and Performances	119
8.3.1	Device Structure and Design	119
8.3.2	Device Fabrication	121
8.3.3	The Device Performances	122
	References	124
9	High Sensitive Sensors Based on FBAR	125
9.1	Microbalance Sensor Based on Piezoelectric Quartz Crystal	125
9.1.1	Quartz Crystal Microbalance.....	125
9.1.2	The Sensing Principle of Piezoelectric Crystal.....	126
9.1.3	Measuring Method of Piezoelectric Crystal Resonance Sensor.....	129
9.2	The Sensitive Material of Piezoelectric Crystal Sensor	129
9.2.1	The Requirement and Mechanism of Adsorption	129
9.2.2	Coating Methods of Sensitive Material	130
9.2.3	Application of Piezoelectric Crystal Sensor	131
9.3	Carbon Nanotubes Sensitive Material	134
9.3.1	Adsorption Property of CNTs	134
9.3.2	Application of CNTs as Adsorbed Layer	135
9.4	Sensors Base on FBAR	136
9.4.1	The Sensing Principle of FBAR.....	136
9.4.2	MBVD Circuits of FBAR Sensor	139
9.4.3	Substance Testing with FBAR	140
9.4.4	Other FBAR-Based Detections	143
9.5	FBAR Sensor Coated with CNTs Sensitive Material	143
9.5.1	Formation Method of CNTs Selective Layer	144
9.5.2	Example of FBAR Sensor	144
9.5.3	Mass Sensitivity of Sensor Frequency	145
9.5.4	Frequency Response to Added Mass of CNTs Deposition Layer	146
9.5.5	The Frequency Response to CNTs Adsorption.....	147
	References	148
	Index	151