

Contents

List of Contributors	XIII
1 Direct Bonding, Fusion Bonding, Anodic Bonding, Wafer Bonding: A Historical Patent Picture of the Worldwide Moving Front of the State-of-the-Art of Contact Bonding.....	1
J. Haisma	
1.1 Relevant Patents in a Broader Scope.....	1
1.2 A Monopolistic Utilitarian Framework	2
1.3 Physical Background and Object in View	3
1.4 The Pre-patent Period of Direct Bonding	5
1.5 Bonding Patents Pre-World War II	6
1.6 The Rise of Bonding Patents Post-World War II	7
1.7 The Novel Face of Classical Electro-optics	9
1.8 Fusion Bonding	13
1.9 Anodic Bonding	17
1.10 Specific Bonding Matters	19
1.11 Bonding Diversity	28
1.12 Inorganic-Atoms-Supported Bonding	31
1.13 Silicon-on-Insulator (SOI).....	34
1.14 Some SOI Topics	39
1.15 Isolated-Pocket SOI.....	42
1.16 Semiconductor-on-Semiconductor Wafer Bonding.....	44
1.17 Sensor Technology	47
1.18 Medical Applications	49
1.19 Patents' Future.....	51
References.....	54
2 Basics of Silicon-on-Insulator (SOI) Technology	61
J.-P. Colinge	
2.1 Introduction: What is Silicon-on-Insulator?	61
2.2 General Properties of SOI Devices.....	64
2.3 The SOI MOS Transistor	67
2.4 SOI Circuit Applications	77
2.5 Conclusion.....	79
References.....	79
3 Silicon-on-Insulator by the Smart CutTM Process	85
G. K. Celler, A. J. Auberton-Hervé, B. Aspar, C. Lagahe-Blanchard, and C. Maleville	

3.1	Introduction	85
3.2	Discovery of Controlled Exfoliation	85
3.3	Process Description	86
3.4	Hydrogen Splitting/Separation Mechanism	88
3.5	Variations on Wafer Bonding and Hydrogen-Related Splitting ...	95
3.6	Large-Scale Manufacturing of SOI Wafers for Advanced CMOS.....	98
3.7	Ultrathin Products	100
3.8	Conclusions	102
	References.....	104
4	ELTRAN® Technology Based on Wafer Bonding and Porous Silicon.....	107
K. Sakaguchi and T. Yonehara		
4.1	Introduction	107
4.2	Special Features of ELTRAN®	109
4.3	Processes and a Cleanroom	111
4.4	Product quality	122
4.5	Mass Production.....	126
4.6	Cost-Effectiveness.....	127
4.7	Potential.....	149
4.8	Conclusions	153
	References.....	154
5	Wafer Bonding for High-Performance Logic Applications.....	157
K.W. Guarini and H.-S. P. Wong		
5.1	Introduction	157
5.2	Novel Device Structures – Double-Gate Field Effect Transistors	158
5.3	Novel Device Materials – Strained Silicon-on-insulator.....	166
5.4	Three-Dimensional Integration	170
5.5	Summary	185
	References.....	186
6	Application of Bonded Wafers to the Fabrication of Electronic Devices	193
A. W. Nevin		
6.1	Introduction	193
6.2	Trench-Isolated SOI Structures	193
6.3	Multiple-Layered and Patterned SOI Structures	231
6.4	Silicided SOI Structures	233
6.5	Silicon-on-Silicon Bonding.....	238
	References.....	251

7 Compound Semiconductor Heterostructures by Smart CutTM: SiC On Insulator, QUASICTM Substrates, InP and GaAs Heterostructures on Silicon	263
L. Di Cioccio, E. Jalaguier, and F. Leterre	
7.1 Introduction	263
7.2 SiC on Insulator: SICOI	265
7.3 Properties of the SiC Layer after Smart Cut TM Transfer.....	270
7.4 SiC Epitaxy	274
7.5 Heteroepitaxy of GaN	275
7.6 Devices on SICOI.....	279
7.7 Characterization of SICOI n-Type 4H-SiC Thin Film Piezoresistors in a Pressure Sensor for High-Temperature Applications	284
7.8 QUASIC TM Smart Cut TM Substrates for SiC High-Power Devices	288
7.9 III-V layers transfer by the Smart Cut TM Process	293
7.10 Conclusions	309
References.....	310
8 Three-Dimensional Photonic Bandgap Crystals by Wafer Bonding Approach	315
S. Noda	
8.1 Introduction	315
8.2 Fabrication and Optical Properties of 3D Photonic Crystals at Infrared to Near-Infrared Wavelengths.....	316
8.3 Summary	324
References.....	325
9 Wafer Direct Bonding for High-Brightness Light-Emitting Diodes and Vertical-Cavity Surface-Emitting Lasers	327
A. Plößl	
9.1 High-brightness Light-Emitting Diodes	327
9.2 Transparent-Substrate AlGaInP LEDs	333
9.3 Alternative Bonding Methods for LEDs	341
9.4 Long-Wavelength Vertical-Cavity Surface-Emitting Laser Devices	346
References.....	353
10 High-Density Hybrid Integration of III-V Compound Optoelectronics with Silicon Integrated Circuits	359
E.D. Kyriakis-Bitzaros and G. Halkias	
10.1 Introduction	359
10.2 Flip-Chip Assembly of III-V OE on CMOS Dies.....	360
10.3 Epitaxial Lift-off.....	363
10.4 Appliqué	366

10.5	Low-Temperature Wafer Bonding	368
10.6	Fluidic Self-Assembly Technologies	371
10.7	Concluding Remarks	374
	References.....	374
11	Layer Transfer by Bonding and Laser Lift-Off	377
T.D. Sands, W.S. Wong, and N.W. Cheung		
11.1	Introduction	377
11.2	Optical, Thermal, Mechanical and Chemical Responses to Pulsed Laser Irradiation of Solid Interfaces	384
11.3	Process Flows for Layer Transfer by Laser Lift-Off	392
11.4	Specific Material Systems	396
11.5	Applications of Laser Lift-Off	403
11.6	Issues in the Scale-up of Laser Lift-off for Manufacturing	408
11.7	Prospects and Potential Impact of Laser Lift-Off.....	410
	References.....	411
12	Single-Crystal Lithium Niobate Films by Crystal Ion Slicing.....	417
M. Levy and A. M. Radojevic		
12.1	Background	417
12.2	Properties of Bulk Lithium Niobate	417
12.3	The Crystal Ion Slicing Process	420
12.4	Thin Film Layer Transfer Using Crystal Ion Slicing	424
12.5	CIS Process for Active-Control Integrated Optic Devices	433
12.6	Thin-film Bonding and Hybrid Integration	434
12.7	Optical Properties of Sliced LiNbO ₃ Films	434
12.8	Quasi-Phase-Matching in Single-Crystal Periodically-Poled LiNbO ₃ Films.....	438
12.9	Zero-Order CIS Film Wave-Retarders	440
12.10	Crystal-Ion-Sliced Thin Film Pyroelectric Detectors.....	443
12.11	Conclusion	446
	References.....	447
13	Wafer Bonding of Ferroelectric Materials.....	451
M. Alexe, I. Radu, and I. Szafraniak		
13.1	Introduction	451
13.2	Transfer of Polycrystalline Ferroelectric Layers	453
13.3	Ferroelectric MOS Devices by Layer Transfer	458
13.4	Single-Crystalline Ferroelectric Thin Film	466
13.5	Conclusions	469
	References.....	470

14 Debonding of Wafer-Bonded Interfaces for Handling and Transfer Applications	473
J. Bagdahn and M. Petzold	
14.1 Introduction	473
14.2 Debonding Methods	476
14.3 Applications and Debonding Devices	487
References.....	493
Index.....	495