

# Contents

Preface	xi
<b>1 Porous SiC Preparation, Characterization and Morphology</b>	<b>1</b>
1.1 Introduction	1
1.2 Triangular Porous Morphology in n-type 4H-SiC	2
1.2.1 Crystal Anodization	2
1.2.2 Description of the Porous Structure	3
1.2.3 Model of the Morphology	9
1.3 Nano-columnar Pore Formation in 6H-SiC	15
1.3.1 Experimental	15
1.3.2 Results	16
1.3.3 Discussion	18
1.4 Summary	26
Acknowledgements	27
References	27
<b>2 Processing Porous SiC: Diffusion, Oxidation, Contact Formation</b>	<b>31</b>
2.1 Introduction	31
2.2 Formation of Porous Layer	32
2.3 Diffusion in Porous SiC	42
2.4 Oxidation	47
2.5 Contacts to Porous SiC	49
Acknowledgements	53
References	53
<b>3 Growth of SiC on Porous SiC Buffer Layers</b>	<b>55</b>
3.1 Introduction	55
3.2 SiC CVD Growth	57

3.3	Growth of 3C-SiC on Porous Si via Cold-Wall Epitaxy	58
3.3.1	Growth on Porous Si Substrates	58
3.3.2	Growth on Stabilized Porous Si Substrates	62
3.4	Growth of 3C-SiC on Porous 3C-SiC	64
3.4.1	Growth in LPCVD Cold-wall Reactor	64
3.5	Growth of 4H-SiC on Porous 4H-SiC	67
3.6	Conclusion	73
	Acknowledgements	74
	References	74
<b>4</b>	<b>Preparation and Properties of Porous GaN Fabricated by Metal-Assisted Electroless Etching</b>	<b>77</b>
4.1	Introduction	77
4.2	Creation of Porous GaN by Electroless Etching	78
4.3	Morphology Characterization	80
4.3.1	Porous GaN Derived from Unintentionally Doped Films	80
4.3.2	Transmission Electron Microscopy (TEM) Characterization	84
4.4	Luminescence of Porous GaN	85
4.4.1	Cathodoluminescence (CL) of Porous GaN	86
4.4.2	Photoluminescence (PL) of Porous GaN	88
4.5	Raman Spectroscopy of Porous GaN	89
4.5.1	Characteristics of Raman scattering in GaN	89
4.5.2	Raman Spectra of Porous GaN Excited Below Band Gap	91
4.6	Summary and Conclusions	95
	Acknowledgements	95
	References	95
<b>5</b>	<b>Growth of GaN on Porous SiC by Molecular Beam Epitaxy</b>	<b>101</b>
5.1	Introduction	101
5.2	Morphology and Preparation of Porous SiC Substrates	104
5.2.1	Porous Substrates	104
5.2.2	Hydrogen Etching	105

CONTENTS	vii
5.3 MBE Growth of GaN on Porous SiC Substrates	108
5.3.1 Experimental Details	108
5.3.2 Film Structure	110
5.3.3 Film Strain	114
5.4 Summary	116
Acknowledgements	117
References	117
<b>6 GaN Lateral Epitaxy Growth Using Porous SiN<sub>x</sub>, TiN<sub>x</sub> and SiC</b>	<b>121</b>
6.1 Introduction	121
6.2 Epitaxy of GaN on Porous SiN <sub>x</sub> Network	122
6.2.1 Three-step Growth Method	123
6.2.2 Structural and Optical Characterization	128
6.2.3 Schottky Diodes (SDs) on Undoped GaN Templates	135
6.2.4 Deep Level Transition Spectrum	138
6.3 Epitaxial Lateral Overgrowth of GaN on Porous TiN	140
6.3.1 Formation of Porous TiN	140
6.3.2 Growth of GaN on Porous TiN	142
6.3.3 Characterization by XRD	146
6.3.4 Characterization by TEM	146
6.3.5 Characterization by PL	152
6.4 Growth of GaN on Porous SiC	154
6.4.1 Fabrication of Porous SiC	156
6.4.2 GaN Growth on Hydrogen Polished Porous SiC	157
6.4.3 GaN Growth on Chemical Mechanical Polished Porous SiC	164
Acknowledgements	167
References	167
<b>7 HVPE Growth of GaN on Porous SiC Substrates</b>	<b>171</b>
7.1 Introduction	171
7.2 PSC Substrate Fabrication and Properties	172
7.2.1 Formation of Various Types of SPSC Structure	173
7.2.2 Dense Layer	177
7.2.3 Monitoring of Anodization Process	178

7.2.4	Vacancy Model of Primary Pore Formation	183
7.2.5	Stability of SPSC Under Post-Anodization Treatment	190
7.3	Epitaxial Growth of GaN Films on PSC Substrates	195
7.3.1	The Growth and Its Effect on the Structure of the PSC Substrate	195
7.3.2	Properties of the GaN Films Grown	198
7.4	Summary	206
	References	207
<b>8</b>	<b>Dislocation Mechanisms in GaN Films Grown on Porous Substrates or Interlayers</b>	<b>213</b>
8.1	Introduction	213
8.2	Extended Defects in Epitaxially Grown GaN Thin Layers	214
8.3	Dislocation Mechanisms in Conventional Lateral Epitaxy Overgrowth of GaN	217
8.4	Growth of GaN on Porous SiC Substrates	220
8.5	Growth of GaN on Porous SiN and TiN Interlayers	222
8.5.1	GaN Growth on a TiN Interlayer	223
8.5.2	GaN Growth on a SiN Interlayer	224
8.6	Summary	226
	Acknowledgements	227
	References	227
<b>9</b>	<b>Electrical Properties of Porous SiC</b>	<b>231</b>
9.1	Introduction	231
9.2	Resistivity and Hall Effect	232
9.3	Deep Level Transient Spectroscopy	234
9.3.1	Fundamentals of DLTS	234
9.3.2	Method of Solving the General Equation	236
9.4	Sample Considerations	237
9.5	Potential Energy Near a Pore	238
9.6	DLTS Data and Analysis	240
	Acknowledgements	243
	References	243

CONTENTS	ix
<b>10 Magnetism of Doped GaN Nanostructures</b>	<b>245</b>
10.1 Introduction	245
10.2 Mn-Doped GaN Crystal	247
10.3 Mn-Doped GaN Thin Films	248
10.3.1 Mn-Doped GaN (11 $\bar{2}$ 0) Surface	249
10.3.2 Mn-Doped GaN (10 $\bar{1}$ 0) Surface	252
10.3.3 Mn and C Codoped in GaN (10 $\bar{1}$ 0) Surface	257
10.4 Mn- and Cr-Doped GaN One-Dimensional Structures	259
10.4.1 Mn-Doped GaN Nanowires	259
10.4.2 Cr-Doped GaN Nanotubes	262
10.4.3 Cr-Doped GaN Nanohole Arrays	265
10.5 N-Doped Mn and Cr Clusters	268
10.5.1 Giant Magnetic Moments of Mn <sub>x</sub> N Clusters	268
10.5.2 N-induced Magnetic Transition in Small Cr <sub>x</sub> N Clusters	269
10.6 Summary	270
Acknowledgements	271
References	271
<b>11 SiC Catalysis Technology</b>	<b>275</b>
11.1 Introduction	275
11.2 Silicon Carbide Support	276
11.3 Heat Effects During Reaction	277
11.4 Reactions on SiC as Catalytic Supports	278
11.5 Examples of SiC Catalyst Applications	279
11.5.1 Pt/ $\beta$ -SiC Catalyst for Catalytic Combustion of Carbon Particles in Diesel Engines	279
11.5.2 Complete Oxidation of Methane	280
11.5.3 SiC-Supported MoO <sub>3</sub> -Carbon-Modified Catalyst for the <i>n</i> -Heptane Isomerization	280
11.5.4 Selective Oxidation of H <sub>2</sub> S Over SiC-Supported Iron Catalysts into Elemental Sulfur	281

11.5.5	Partial Oxidation of <i>n</i> -Butane to Maleic Anhydride Using SiC-Mixed and Pd-Modified Vanadyl Pyrophosphate (VPO) Catalysts (Case study)	282
11.6	Prospects and Conclusions	288
	References	289
<b>12</b>	<b>Nanoporous SiC as a Semi-Permeable Biomembrane for Medical Use: Practical and Theoretical Considerations</b>	<b>291</b>
12.1	The Rationale for Implantable Semi-Permeable Materials	291
12.2	The Biology of Soluble Signaling Proteins in Tissue	292
12.3	Measuring Cytokine Secretion In Living Tissues and Organs	294
12.4	Creating a Biocompatible Tissue – Device Interface: Advantages of SiC	295
12.5	The Testing of SiC Membranes for Permeability of Proteins	296
12.6	Improving the Structure of SiC Membranes for Biosensor Interfaces	299
12.7	Theoretical Considerations: Modeling Diffusion through a Porous Membrane	301
12.7.1	Effective Medium Models for a Porous Membrane	302
12.7.2	Comparison with Experiment	304
12.8	Future Development: Marriage of Membrane and Microchip	305
12.9	Conclusions	307
	Acknowledgements	307
	References	308
	<b>Index</b>	<b>311</b>