

# Table of Contents

Sponsors	v
Committees	vii
Preface	ix
Overview	xi

## Part 1:

### **Chapter 1. SiC Bulk Growth**

<b>Reduction of Dislocations in the Bulk Growth of SiC Crystals</b>	
D. Nakamura .....	3
<b>The Spatial Distribution of Defects and its Dependence on Seed Polarity and Off-Orientation during Growth of 4H-SiC Single Crystals</b>	
H.-J. Rost, M. Schmidbauer and D. Siche .....	9
<b>Fundamental Limitations of SiC PVT Growth Reactors with Cylindrical Heaters</b>	
R. Drachev, E. Deyneka, C. Rhodes, J. Schupp and T. Sudarshan .....	15
<b>Halide-CVD Growth of Bulk SiC Crystals</b>	
A.Y. Polyakov, M.A. Fanton, M. Skowronski, H.J. Chung, S. Nigam and S.W. Huh .....	21
<b>Growth Kinetics and Polytype Stability in Halide Chemical Vapor Deposition of SiC</b>	
S. Nigam, H.J. Chung, S.W. Huh, J. Grim, A.Y. Polyakov, M.A. Fanton, B. Weiland, D.W. Snyder and M. Skowronski .....	27
<b>Enhanced Carrier Lifetime in Bulk-Grown 4H-SiC Substrates</b>	
J.R. Jenny, D.P. Malta, V.T. Tsvetkov, M.K. Das, H.McD. Hobgood and C.H. Carter, Jr. ....	31
<b>Growth of Micropipe Free Crystals on 4H-SiC {03-38} Seeds</b>	
T. Furusho, R. Kobayashi, T. Nishiguchi, M. Sasaki, K. Hirai, T. Hayashi, H. Kinoshita and H. Shiomi .....	35
<b>Growth of Micropipe-Free Single Crystal Silicon Carbide (SiC) Ingots via Physical Vapor Transport (PVT)</b>	
C. Basceri, I. Khlebnikov, Y. Khlebnikov, P. Muzykov, M. Sharma, G. Stratiy, M. Silan and C. Balkas .....	39
<b>Growth and Characterization of Large Diameter 6H and 4H SiC Single Crystals</b>	
A. Gupta, E. Semenas, E. Emorhokpor, J. Chen, I. Zwieback, A. Souzis and T. Anderson .....	43
<b>Growth of SiC Boules with Low Boron Concentration</b>	
M.A. Fanton, R.L. Cavalero, R.G. Ray, B.E. Weiland, W. Everson, D. Snyder, R. Gamble and E. Oslosky .....	47
<b>Resistivity Distribution in Undoped 6H-SiC Boules and Wafers</b>	
Q. Li, A.Y. Polyakov, M. Skowronski, E.K. Sanchez, M.J. Loboda, M.A. Fanton, T. Bogart, D. Gamble, N.B. Smirnov and Yu. Makarov.....	51
<b>The Method for Enhancing Nitrogen Doping in 6H-SiC Single Crystals Grown by Sublimation Process: The Effect of Si Addition in SiC Powder Source</b>	
K.-M. Kim, S.-H. Seo, J.-W. Kim, J.-S. Song, M.-H. Oh, W. Bahng and E.-D. Kim .....	55
<b>A Study of Nitrogen Incorporation in PVT Growth of n<sup>+</sup> 4H SiC</b>	
D.M. Hansen, G. Chung and M.J. Loboda .....	59

<b>In-situ Observation of Mass Transfer in the CF-PVT Growth Process by X-Ray Imaging</b>	63
D. Chaussende, P. Wellmann, M. Ucar, M. Pons and R. Madar .....	63
<b>Growth and Surface Morphologies of 6H SiC Bulk and Epitaxial Crystals</b>	67
G. Dhanaraj, Y. Chen, M. Dudley and H. Zhang .....	67
<b>Processing of Poly-SiC Substrates with Large Grains for Wafer-Bonding</b>	
G. Chichignoud, L. Auvray, E. Blanquet, M. Anikin, E. Pernot, J.-M. Bluet, P. Chaudouët, M. Mermoux, C. Moisson, F. Letertre, M. Pons and R. Madar .....	71
<b>Modeling and Experimental Verification of SiC M-PVT Bulk Crystal Growth</b>	
P. Wellmann, R. Müller and M. Pons .....	75
<b>Basal Plane Dislocation Dynamics in Highly p-type Doped versus Highly n-type Doped SiC</b>	
P. Wellmann, D. Queren, R. Müller, S.A. Sakwe and U. Künecke .....	79
<b>High Quality SiC Crystals Grown by the Physical Vapor Transport Method with a New Crucible Design</b>	
K.-R. Ku, J.-G. Kim, J.-D. Seo, J.-Y. Lee, M.-O. Kyun, W.-J. Lee, G.-H. Lee, I.-S. Kim and B.-C. Shin .....	83
<b>Active Thermal Interaction of Source and Crystal Surfaces in PVT SiC Crystal Growth</b>	
K. Grasza, E. Tymicki and J. Kisielewski .....	87
<b>The Influence of SiC Powder Source on 6H-SiC Single Crystals Grown by the Sublimation Method</b>	
J.-W. Kim, S.-H. Seo, K.-M. Kim, J.-S. Song, T.-S. Kim and M.-H. Oh .....	91
<b>Polytype Control in 6H-SiC Grown via Sublimation Method</b>	
X. Li, S. Jiang, X. Hu, J. Dong, J. Li, X. Chen, L. Wang, X. Xu and M. Jiang .....	95
<b>Characterization of Bulk &lt;111&gt; 3C-SiC Single Crystals Grown on 4H-SiC by the CF-PVT Method</b>	
L. Latu-Romain, D. Chaussende, C. Balloud, S. Juillaguet, L. Rapenne, E. Pernot, J. Camassel, M. Pons and R. Madar .....	99
<b>Hybrid Physical-Chemical Vapor Transport Growth of SiC Bulk Crystals</b>	
M.A. Fanton, Q. Li, A.Y. Polyakov, R.L. Cavalero, R.G. Ray, B.E. Weiland and M. Skowronski .....	103
<b>SiC HTCVD Simulation Modified by Sublimation Etching</b>	
Y. Kitou, E. Makino, K. Ikeda, M. Nagakubo and S. Onda .....	107
<b>Gas Fed Top-Seeded Solution Growth of Silicon Carbide</b>	
D. Chaussende, M. Pons and R. Madar .....	111
<b>Growth of SiC Single Crystal from Si-C-(Co, Fe) Ternary Solution</b>	
N. Yashiro, K. Kusunoki, K. Kamei, M. Hasebe, T. Ujihara and K. Nakajima .....	115
<b>Solution Growth of SiC Crystal with High Growth Rate Using Accelerated Crucible Rotation Technique</b>	
K. Kusunoki, K. Kamei, N. Okada, N. Yashiro, A. Yauchi, T. Ujihara and K. Nakajima.....	119
<b>Growth of Cubic Silicon Carbide Crystals from Solution</b>	
J. Eid, J.L. Santailler, B. Ferrand, P. Ferret, J. Pesenti, A. Basset, A. Passero, A. Mantzari, E.K. Polychroniadis, C. Balloud, P. Soares and J. Camassel .....	123

## Chapter 2. SiC Epitaxial Growth

## **2.1 Homoepitaxial Growth**

<b>Recent Progress of SiC Hot-Wall Epitaxy and its Modeling</b>	129
S. Nishizawa and M. Pons .....	129
<b>Challenges in Large-Area Multi-Wafer SiC Epitaxy for Production Needs</b>	135
B. Thomas, C. Hecht, R. Stein and P. Friedrichs .....	135
<b>Techniques for Minimizing the Basal Plane Dislocation Density in SiC Epilayers to Reduce V<sub>f</sub> Drift in SiC Bipolar Power Devices</b>	141
J.J. Sumakeris, J.P. Bergman, M.K. Das, C. Hallin, B.A. Hull, E. Janzén, H. Lendenmann, M.J. O'Loughlin, M.J. Paisley, S. Ha, M. Skowronski, J.W. Palmour and C.H. Carter, Jr. .....	141
<b>Investigation of in-grown Dislocations in 4H-SiC Epitaxial Layers</b>	147
K. Kojima, T. Kato, S. Kuroda, H. Okumura and K. Arai .....	147
<b>4H-SiC Epitaxial Growth on Carbon-Face Substrates with Reduced Surface Roughness</b>	153
T. Aigo, M. Sawamura, T. Fujimoto, M. Katsuno, H. Yashiro, H. Tsuge, M. Nakabayashi, T. Hoshino and N. Ohtani .....	153
<b>SiC Warm-Wall Planetary VPE Growth on Multiple 100-mm Diameter Wafers</b>	159
A.A. Burk, M.J. O'Loughlin, M.J. Paisley, A.R. Powell, M.F. Brady, R.T. Leonard and D.A. McClure .....	159
<b>Epitaxial Layers Grown with HCl Addition: A Comparison with the Standard Process</b>	163
F. La Via, G. Galvagno, A. Firrincieli, F. Roccaforte, S. Di Franco, A. Ruggiero, M. Barbera, R. Reitano, P. Musumeci, L. Calcagno, G. Foti, M. Mauceri, S. Leone, G. Pistone, F. Portuese, G. Abbondanza, G. Abagnale, G.L. Valente and D. Crippa .....	163
<b>Lower-Temperature Epitaxial Growth of 4H-SiC Using CH<sub>3</sub>Cl Carbon Gas Precursor</b>	167
Y. Koshka, H.-D. Lin, G. Melnychuk and C. Wood .....	167
<b>Investigation of the Mechanism and Growth Kinetics of Homoepitaxial 4H-SiC Growth Using CH<sub>3</sub>Cl Carbon Precursor</b>	171
H.-D. Lin, J.L. Wyatt and Y. Koshka .....	171
<b>Homoepitaxial Growth of 4H-SiC Using a Chlorosilane Silicon Precursor</b>	175
M.F. MacMillan, M.J. Loboda, G. Chung, E. Carlson and J. Wan .....	175
<b>SiC-4H Epitaxial Layer Growth Using Trichlorosilane (TCS) as Silicon Precursor</b>	179
S. Leone, M. Mauceri, G. Pistone, G. Abbondanza, F. Portuese, G. Abagnale, G.L. Valente, D. Crippa, M. Barbera, R. Reitano, G. Foti and F. La Via .....	179
<b>Properties of Thick n- and p-type Epitaxial Layers of 4H-SiC Grown by Hot-Wall CVD on off- and on-axis Substrates</b>	183
Jawad-ul-Hassan, C. Hallin, J.P. Bergman and E. Janzén .....	183
<b>High Epitaxial Growth Rate of 4H-SiC Using Horizontal Hot-Wall CVD</b>	187
R.L. Myers, Y. Shishkin, O. Kordina, I. Haselbarth and S.E. Saddow .....	187
<b>Homoepitaxial Growth and Characterization of 4H-SiC Epilayers by Low-Pressure Hot-Wall Chemical Vapor Deposition</b>	191
G. Sun, J. Ning, Q. Gong, X. Gao, L. Wang, X. Liu, Y. Zeng and J. Li .....	191
<b>Highly Uniform SiC Epitaxy for MESFET Fabrication</b>	195
J. Zhang, J. Mazzola, C. Hoff, C. Rivas, E. Romano, J.R.B. Casady, M. Mazzola, J.B. Casady and K. Matocha .....	195

## **Optimisation of Epitaxial Layer Growth by Schottky Diodes Electrical Characterization**

- F. La Via, G. Galvagno, A. Firrincieli, F. Roccaforte, S. Di Franco, A. Ruggiero, L. Calcagno, G. Foti, M. Mauceri, S. Leone, G. Pistone, G. Abbondanza, F. Portuese, G. Abagnale, G.L. Valente and D. Crippa ..... 199

## **High Purity SiC Epitaxial Growth by Chemical Vapor Deposition Using CH<sub>3</sub>SiH<sub>3</sub> and C<sub>3</sub>H<sub>8</sub> Sources**

- T. Hatayama, H. Yano, Y. Uraoka and T. Fuyuki ..... 203

## **Selective Etching of Micropipes During Initial Homoepitaxial Growth Stage on Nearly on-axis 4H-SiC Substrates**

- W. Bahng, H.J. Cheong, I.H. Kang, S.C. Kim, K. Kim and N. Kim ..... 207

## **Proposal of the Thermal Equilibrium Model for SiC Hydrogen Etching Phenomena**

- Y. Ishida, T. Takahashi, H. Okumura, K. Arai, K. Kimura, K. Nakamura and S. Yoshida ..... 211

## **Homoepitaxial Growth of Iron-doped 4H-SiC Using BTMSM and t-butylferrocene Precursors for Semi-insulating Property**

- H.K. Song, J.H. Moon, J.H. Yim and H.J. Kim ..... 215

## **Epitaxial Growth of 4H-SiC on 4° Off-Axis (0001) and (000-1) Substrates by Hot-Wall CVD**

- K. Wada, T. Kimoto, K. Nishikawa and H. Matsunami ..... 219

## **Epitaxial Growth of 4H-SiC {0001} with Large Off-Angles by Chemical Vapor Deposition**

- H. Saitoh, A. Manabe and T. Kimoto ..... 223

## **Stability of Thick Layers Grown on (1-100) and (11-20) Orientations of 4H-SiC**

- M. Syväjärvi, R. Yakimova, G.R. Yazdi, A. Arjunan, E. Toupitsyn and T.S. Sudarshan ..... 227

## **Comparison of Propagation and Nucleation of Basal Plane Dislocations in 4H-SiC(000-1) and (0001) Epitaxy**

- H. Tsuchida, I. Kamata, T. Miyanagi, T. Nakamura, K. Nakayama, R. Ishii and Y. Sugawara ..... 231

## **Ab Initio Studies of the Surface Reaction of Si<sub>2</sub>C and SiC<sub>2</sub> with Si on the 4H-SiC (000-1) Surface**

- H. Yamaguchi, Y. Sakiyama, E. Makino, S. Onda and Y. Matsumoto ..... 235

## **Thick Epitaxial Layers on 4° Off-Oriented 4H-SiC Suited for PiN-Diodes with Blocking Voltages above 6.5 kV**

- C. Hecht, B. Thomas and W. Bartsch ..... 239

## **Growth of Low Basal Plane Dislocation Density SiC Epitaxial Layers**

- Z. Zhang and T.S. Sudarshan ..... 243

## **Experimental Observations of Extended Growth of 4H-SiC Webbed Cantilevers**

- A.J. Trunek, P.G. Neudeck and D.J. Spry ..... 247

## **SiC Migration Enhanced Embedded Epitaxial (ME<sup>3</sup>) Growth Technology**

- Y. Takeuchi, M. Kataoka, T. Kimoto, H. Matsunami and R.K. Malhan ..... 251

## **CVD Epitaxial Growth of 4H-SiC on Porous SiC Substrates**

- Y. Shishkin, Y. Ke, F. Yan, R.P. Devaty, W.J. Choyke and S.E. Saddow ..... 255

## **Studies on Selective Growth and In-Situ Etching of 4H-SiC Using a TaC Mask**

- C. Li, I. Bhat and T.P. Chow ..... 259

## **6H-SiC Homoepitaxial Growth and Optical Property of Boron- and Nitrogen-Doped Donor-Acceptor Pair (DAP) Emission of 1°-off Substrate by Closed-Space Sublimation Method**

- Y. Kawai, T. Maeda, Y. Nakamura, Y. Sakurai, M. Iwaya, S. Kamiyama, H. Amano, I. Akasaki, M. Yoshimoto, T. Furusho, H. Kinoshita and H. Shiomi ..... 263

## **Epitaxial Growth of 4H-SiC (0001) by Sublimation Method Using Horizontal Furnace**

- C.-K. Park, J.-H. An, W.-J. Lee, B.-C. Shin and S. Nishino ..... 267

## **Using Vapour-Liquid-Solid Mechanism for SiC Homoepitaxial Growth on on-axis $\alpha$ -SiC (0001) at Low Temperature**

- M. Soueidan, G. Ferro, F. Cauwet, L. Mollet, C. Jacquier, G. Younes and Y. Monteil ..... 271

## **Improvement of 4H-SiC Selective Epitaxial Growth by VLS Mechanism Using Al and Ge Based Melts**

- G. Ferro, M. Soueidan, C. Jacquier, P. Godignon, Th. Stauden, J. Pezoldt, M. Lazar, J. Montserrat and Y. Monteil ..... 275

## **2.2 Heteropolytypic and Heteroepitaxial Growth**

### **Relaxation Mechanism of the Defect-Free 3C-SiC Epitaxial Films Grown on Step-Free 4H SiC Mesas**

- H. Du, M. Skowronski, P.G. Neudeck, A.J. Trunek, D.J. Spry and J.A. Powell ..... 279

### **Structure Evolution of 3C-SiC on Cubic and Hexagonal Substrates**

- R. Yakimova, G. Reza Yazdi, N. Sritirawisarn and M. Syväjärvi ..... 283

### **Single-Domain 3C-SiC Epitaxially Grown on 6H-SiC by the VLS Mechanism**

- M. Soueidan, G. Ferro, J. Stoemenos, E.K. Polychroniadis, D. Chaussende, F. Soares, S. Juillaguet, J. Camassel and Y. Monteil ..... 287

### **'Switch-Back Epitaxy' as a Novel Technique for Reducing Stacking Faults in 3C-SiC**

- K. Yagi, T. Kawahara, N. Hatta and H. Nagasawa ..... 291

### **Growth Acceleration in FLASiC Assisted Short Time Liquid Phase Epitaxy by Melt Modification**

- J. Pezoldt, F.M. Morales, Th. Stauden, Ch. Förster, E. Polychroniadis, J. Stoemenos, D. Panknin and W. Skorupa ..... 295

### **Hetero-epitaxial Growth of 3C-SiC on Silicon Substrates by Plasma Assisted CVD**

- H. Shimizu and Y. Aoyama ..... 299

### **Selective Epitaxial Growth of 3C-SiC on Si Using Hexamethyldisilane in a Resistance Heated MOCVD Reactor**

- A. Gupta and C. Jacob ..... 303

### **Growth of 3C-SiC on Si Molds for MEMS Applications**

- M. Reyes, M. Waits, S. Harvey, Y. Shishkin, B. Geil, J.T. Wolan and S.E. Saddow ..... 307

### **Nitrogen-Doping of Polycrystalline 3C-SiC Films Deposited by Low Pressure Chemical Vapor Deposition**

- X.-A. Fu, J. Trevino, M. Mehregany and C. Zorman ..... 311

### **Multi-Scale Simulation of MBE-Grown SiC/Si Nanostructures**

- A.A. Schmidt, Yu.V. Trushin, K.L. Safonov, V.S. Kharlamov, D.V. Kulikov, O. Ambacher and J. Pezoldt ..... 315

## **Chapter 3. Physical Properties and Characterization of SiC**

### **3.1 Extended Defects: Stacking Faults and Dislocations**

#### **Theory of Dislocations in SiC: The Effect of Charge on Kink Migration**

T.A.G. Eberlein, R. Jones and A.T. Blumenau ..... 321

#### **Structure of Carrot Defects in 4H-SiC Epilayers**

X. Zhang, S. Ha, M. Benamara, M. Skowronski, J.J. Sumakeris, S. Ryu, M.J. Paisley and  
M.J. O'Loughlin ..... 327

#### **Characterization of SiC Crystals by Using Deep UV Excitation Raman Spectroscopy**

S. Nakashima and T. Mitani ..... 333

#### **Structures of Comets in a Homoepitaxially Grown 4H-SiC Film Studied by DUV Micro-Raman Spectroscopy**

T. Tomita, S. Matsuo, T. Okada, T. Kimoto, T. Mitani and S. Nakashima ..... 339

#### **Raman Scattering Analyses of Stacking Faults in 3C-SiC Crystals**

T. Mitani, S. Nakashima, H. Okumura and H. Nagasawa ..... 343

#### **Observation of Free Carrier Redistribution Resulting from Stacking Fault Formation in Annealed 4H-SiC**

O.J. Glembocki, M. Skowronski, S.M. Prokes, D.K. Gaskilll and J.D. Caldwell ..... 347

#### **Stacking Faults and 3C Quantum Wells in Hexagonal SiC Polytypes**

M.S. Miao and W.R.L. Lambrecht ..... 351

#### **Silicon Carbide: A Playground for 1D-Modulation Electronics**

P. Deák, A. Buruzs, A. Gali, T. Frauenheim and W.J. Choyke ..... 355

#### **Peierls Barriers and Core Properties of Partial Dislocations in 4H-SiC**

G. Savini, M.I. Heggie and S. Öberg ..... 359

#### **Characterization of Stacking Fault-Induced Behavior in 4H-SiC p-i-n Diodes**

Y. Wang, L. Chen, M.K. Mikhov, G. Samson and B.J. Skromme ..... 363

#### **Recombination Behavior of Stacking Faults in SiC p-i-n Diodes**

S.I. Maximenko, P. Pirouz and T.S. Sudarshan ..... 367

#### **Performance of Silicon Carbide PiN Diodes Fabricated on Basal Plane Dislocation-Free Epilayers**

Z. Zhang, A.E. Grekov, P. Sadagopan, S.I. Maximenko and T.S. Sudarshan ..... 371

#### **Observation of Shrinking and Reformation of Shockley Stacking Faults by PL Mapping**

T. Miyanagi, H. Tsuchida, I. Kamata, T. Nakamura, R. Ishii, K. Nakayama and Y. Sugawara ..... 375

#### **Investigation of Mechanical Stress-Induced Double Stacking Faults in (11-20) Highly N-doped 4H-SiC Combining Optical Microscopy, TEM, Contrast Simulation and Dislocation Core Reconstruction**

M. Lancin, G. Regula, J. Douin, H. Idrissi, L. Ottaviani and B Pichaud ..... 379

#### **Overlapping Shockley/Frank Faults in 4H-SiC PiN Diodes**

M.E. Twigg, R.E. Stahlbush, P.A. Losee, C. Li, I.B. Bhat and T.P. Chow ..... 383

#### **Examining Dislocations in SiC Epitaxy by Light Emission from Simple Diode Structures**

K.X. Liu, R.E. Stahlbush, K.D. Hobart and J.J. Sumakeris ..... 387

#### **Photoemission of 4H-SiC pin Diodes Epitaxied by the Sublimation Method**

N. Camara, K. Zekentes, E. Bano, A. Thuaire and A. Lebedev ..... 391

<b>Investigation of Structural Stability in 4H-SiC Structures with Heavy Ion Implanted Interface</b>	395
A. Galeckas, A. Hallén, A. Schöner, J. Linnros and P. Pirouz .....	
<b>Origin of Surface Morphological Defects in 4H-SiC Homoepitaxial Films</b>	399
T. Okada, K. Okamoto, K. Ochi, K. Higashimine and T. Kimoto .....	
<b>Structure of “Star” Defect in 4H-SiC Substrates and Epilayers</b>	403
J.W. Lee and M. Skowronski .....	
<b>Synchrotron X-ray Topographic Analysis of Dislocation Structures in Bulk SiC Single Crystal</b>	407
S. Yamaguchi, D. Nakamura, I. Gunjishima and Y. Hirose .....	
<b>Simulation of Threading Edge Dislocation Images in X-Ray Topographs of Silicon Carbide Homo-Epitayers</b>	411
W.M. Vetter, H. Tsuchida, I. Kamata and M. Dudley .....	
<b>Development of Non-destructive In-house Observation Techniques for Dislocations and Stacking Faults in SiC Epilayers</b>	415
I. Kamata, H. Tsuchida, T. Miyanagi and T. Nakamura .....	
<b>Why Are Only Some Basal Plane Dislocations Converted to Threading Edge Dislocations During SiC Epitaxy?</b>	419
Z. Zhang, A. Shrivastava and T.S. Sudarshan .....	
<b>3-Dimensional Non-Destructive Dislocation Analyses in SiC Measured by Planar Electron-Beam-Induced Current Method</b>	423
Y. Yanagisawa, T. Hatayama, H. Yano, Y. Uraoka and T. Fuyuki .....	
<b>Effect of Crystal Defects on Reverse I-V Characteristics of 4H-SiC APDs</b>	427
S. Soloviev, P. Sandvik, S. Arthur, K. Matocha, S. Maximenko and T.S. Sudarshan .....	
<b>Structural Defects and Critical Electric Field in 3C-SiC</b>	431
M.A. Capano, A.R. Smith, B.C. Kim, E.P. Kvam, S. Tsoi, A.K. Ramdas and J.A. Cooper .....	
<b>Giant Burgers Vector Micropipe-Dislocations in Silicon Carbide Investigated by Atomic Force Microscopy</b>	435
E. Pernot, J. Härtwig, M. Pons and R. Madar .....	
<b>Open Core Dislocations and Surface Energy of SiC</b>	439
S.I. Maximenko, P. Pirouz and T.S. Sudarshan .....	
<b>Comparison between Measurement Techniques Used for Determination of the Micropipe Density in SiC Substrates</b>	443
E. Emorhokpor, E. Carlson, J. Wan, A. Weber, C. Basceri, J. Jenny, R. Sandhu, J. Oliver, F. Burkeen, A. Somanchi, V. Velidandla, F. Orazio, A. Blew, M. Goorsky, M. Dudley and W.M. Vetter .....	
<b>A New Method of Mapping and Counting Micropipes in SiC Wafers</b>	447
J. Wan, S.-H. Park, G. Chung, E. Carlson and M.J. Loboda .....	
<b>Identification of Polytypes in Sublimation Grown 4H-SiC Crystals by High Resolution X-Ray Diffractometry</b>	451
J. Dong, L. Wang, X. Hu, X. Li, J. Li, S. Jiang, X. Chen, X. Xu and M. Jiang .....	
<b>Optical Studies of Deep Centers in Semi-Insulating SiC</b>	455
B. Magnusson, R. Aavikko, K. Saarinen, N.T. Son and E. Janzén .....	

### 3.2 Point Defects

<b>Optical Studies of Deep Centers in Semi-Insulating SiC</b>	455
B. Magnusson, R. Aavikko, K. Saarinen, N.T. Son and E. Janzén .....	

## **Investigation of the Electronic Structure of the UD-4 Defect in 4H-SiC by Optical Techniques**

- A. Thuaire, A. Henry, B. Magnusson, J.P. Bergman, W.M. Chen, E. Janzén, M. Mermoux and E. Bano ..... 461

## **High Energy Local Vibrational Modes of Carbon Aggregates in SiC: Experimental and Theoretical Insight**

- A. Mattausch, M. Bockstedte, O. Pankratov, J.W. Steeds, S. Furkert, J.M. Hayes, W. Sullivan and N.G. Wright ..... 465

## **Non-equilibrium Carrier Diffusion and Recombination in Semi-insulating PVT Grown Bulk 6H-SiC Crystals**

- K. Neimontas, A. Kadys, R. Aleksiejūnas, K. Jarašiūnas, G. Chung, E. Sanchez and M. Loboda ..... 469

## **Origin of the Up-Conversion Process in 4H SiC**

- J.W. Steeds, S.A. Furkert, W. Sullivan and G. Wagner ..... 473

## **A Combined Photoluminescence and Electron Paramagnetic Resonance Study of Low Energy Electron Irradiated 4H SiC**

- W. Sullivan, J.W. Steeds, H.J. von Bardeleben and J.L. Cantin ..... 477

## **Investigation of the Displacement Threshold of Si in 4H SiC**

- W. Sullivan and J.W. Steeds ..... 481

## **Long Distance Point Defect Migration in Irradiated SiC Observed by Deep Level Transient Spectroscopy**

- G. Alfieri, U. Grossner, E.V. Monakhov, B.G. Svensson, J.W. Steeds and W. Sullivan ..... 485

## **Deep Level Defects Related to Carbon Displacements in n- and p-type 4H-SiC**

- L. Storasta, I. Kamata, T. Nakamura and H. Tsuchida ..... 489

## **Deep Traps and Charge Carrier Lifetimes in 4H-SiC Epilayers**

- S.W. Huh, J.J. Sumakeris, A.Y. Polyakov, M. Skowronski, P.B. Klein, B.V. Shanabrook and M.J. O'Loughlin ..... 493

## **Deep Electron and Hole Traps in 6H-SiC Bulk Crystals Grown by the Halide Chemical Vapor Deposition**

- S.W. Huh, A.Y. Polyakov, H.J. Chung, S. Nigam, M. Skowronski, E.R. Glaser, W.E. Carlos, M.A. Fanton and N.B. Smirnov ..... 497

## **Deep Hole Traps in As-Grown 4H-SiC Epilayers Investigated by Deep Level Transient Spectroscopy**

- K. Danno and T. Kimoto ..... 501

## **Deep Level near $E_c - 0.55$ eV in Undoped 4H-SiC Substrates**

- W.C. Mitchel, W.D. Mitchell, S.R. Smith, G. Landis, A.O. Evvaraye, Z.-Q. Fang, D.C. Look and J.R. Sizelove ..... 505

## **Deep Traps in High-Purity Semi-Insulating 6H-SiC Substrates: Thermally Stimulated Current Spectroscopy**

- Z.-Q. Fang, B. Claflin, D.C. Look, L. Polenta, J. Chen, T. Anderson and W.C. Mitchel ..... 509

## **Quenching Photoconductivity and Photoelectric Memory in 6H-SiC**

- M. Duisenbaev ..... 513

## **Deep Level Point Defects in Semi-Insulating SiC**

- M.E. Zvanut, W. Lee, H. Wang, W.C. Mitchel and W.D. Mitchell ..... 517

## **Divacancy and its Identification: Theory**

- A. Gali, M. Bockstedte, N.T. Son, T. Umeda, J. Isoya and E. Janzén ..... 523

<b>Divacancy Model for P6/P7 Centers in 4H- and 6H-SiC</b>	
N.T. Son, T. Umeda, J. Isoya, A. Gali, M. Bockstedte, B. Magnusson, A. Ellison, N. Morishita, T. Ohshima, H. Itoh and E. Janzén .....	527
<b>Thermal Evolution of Defects in Semi-Insulating 4H SiC</b>	
W.E. Carlos, E.R. Glaser, N.Y. Garces, B.V. Shanabrook and M.A. Fanton .....	531
<b>Evidence of the Ground Triplet State of Silicon-Carbon Divacancies (P6, P7 Centers) in 6H SiC: An EPR Study</b>	
I.V. Ilyin, M.V. Muzafarova, E.N. Mokhov, V.I. Sankin, P.G. Baranov, S.B. Orlinskii and J. Schmidt .....	535
<b>Signature of the Negative Carbon Vacancy-Antisite Complex</b>	
M. Bockstedte, A. Gali, T. Umeda, N.T. Son, J. Isoya and E. Janzén .....	539
<b>Electron Paramagnetic Resonance Study of the HEI4/SI5 Center in 4H-SiC</b>	
T. Umeda, N.T. Son, J. Isoya, N. Morishita, T. Ohshima, H. Itoh and E. Janzén .....	543
<b>Relationship between the EPR SI-5 Signal and the 0.65 eV Electron Trap in 4H- and 6H-SiC Polytypes</b>	
N.Y. Garces, W.E. Carlos, E.R. Glaser, S.W. Huh, H.J. Chung, S. Nigam, A.Y. Polyakov and M. Skowronski .....	547
<b>Carbon Related Split-Interstitials in Electron-Irradiated n-type 6H-SiC</b>	
M.V.B. Pinheiro, E. Rauls, U. Gerstmann, S. Greulich-Weber, J.-M. Spaeth and H. Overhof .....	551
<b>Identification of the Triplet State N-V Defect in Neutron Irradiated Silicon Carbide by Electron Paramagnetic Resonance</b>	
M.V. Muzafarova, I.V. Ilyin, E.N. Mokhov, V.I. Sankin and P.G. Baranov .....	555
<b>Possible Role of Hydrogen within the So-Called X Center in Semi-Insulating 4H-SiC</b>	
E.N. Kalabukhova, S.N. Lukin, D.V. Savchenko, W.C. Mitchel, S. Greulich-Weber, E. Rauls and U. Gerstmann .....	559
<b>Trapping Recombination Process and Persistent Photoconductivity in Semi-Insulating 4H SiC</b>	
E.N. Kalabukhova, S.N. Lukin, D.V. Savchenko, A.A. Sitnikov, W.C. Mitchel, S.R. Smith and S. Greulich-Weber .....	563
<b>Identification of Deep Level Defects in SiC Bipolar Junction Transistors</b>	
P.M. Lenahan, N.T. Pfeiffenberger, T.G. Pribicko and A.J. Lelis .....	567
<b>Vacancy Defects Induced by Low Energy Electron Irradiation in 6H and 3C-SiC Monocrystals Characterized by Positron Annihilation Spectroscopy and Electron Paramagnetic Resonance</b>	
X. Kerbiriou, M.F. Barthe, S. Esnouf, P. Desgardin, G. Blondiaux and G. Petite .....	571
<b>Clustering of Vacancies in Semi-Insulating SiC Observed with Positron Spectroscopy</b>	
R. Aavikko, K. Saarinen, B. Magnusson and E. Janzén .....	575
<b>3.3 Impurities</b>	
<b>3.3.1 Shallow Donors and Acceptors, Hydrogen</b>	
<b>Electronic Raman Studies of Shallow Donors in Silicon Carbide</b>	
R. Püsche, M. Hundhausen, L. Ley, K. Semmelroth, G. Pensl, P. Desperrier, P.J. Wellmann, E.E. Haller, J.W. Ager and U. Starke .....	579
<b>Evidence for Phosphorus on Carbon and Silicon Sites in 6H and 4H SiC</b>	
F. Yan, R.P. Devaty, W.J. Choyke, A. Gali, I.B. Bhat and D.J. Larkin .....	585

<b>Photoluminescence of Phosphorus Doped SiC</b>	
A. Henry and E. Janzén .....	589
<b>Shallow P Donors in 3C-, 4H- and 6H-SiC</b>	
J. Isoya, M. Katagiri, T. Umeda, N.T. Son, A. Henry, A. Gali, N. Morishita, T. Ohshima, H. Itoh and E. Janzén .....	593
<b>Dependence of the Ionization Energy of Phosphorus Donor in 4H-SiC on Doping Concentration</b>	
S. Rao, T.P. Chow and I. Bhat .....	597
<b>Donor-Acceptor Pair Luminescence of Phosphorus-Aluminum and Nitrogen-Aluminum Pairs in 4H SiC</b>	
I.G. Ivanov, A. Henry and E. Janzén .....	601
<b>A Theoretical Study on Doping of Phosphorus in Chemical Vapor Deposited SiC Layers</b>	
T. Hornos, A. Gali, R.P. Devaty and W.J. Choyke .....	605
<b>New Aspects in n-type Doping of SiC with Phosphorus</b>	
E. Rauls, U. Gerstmann, S. Greulich-Weber, K. Semmelroth, G. Pensl and E.E. Haller .....	609
<b>Conditions and Limitations of Using Low-Temperature Photoluminescence to Determine Residual Nitrogen Levels in Semi-Insulating SiC Substrates</b>	
E.R. Glaser, B.V. Shanabrook, W.E. Carlos, H.J. Chung, S. Nigam, A.Y. Polyakov and M. Skowronski .....	613
<b>Evaluating and Improving SIMS Method for Measuring Nitrogen in SiC</b>	
H.E. Smith, K.G. Eyink, W.C. Mitchel, M.C. Wood and M.A. Fanton .....	617
<b>Kinetic Mechanisms for the Deactivation of Nitrogen in SiC</b>	
M. Bockstedte, A. Mattausch and O. Pankratov .....	621
<b>Electrical Properties of Undoped 6H- and 4H-SiC Bulk Crystals Grown by Halide Chemical Vapor Deposition</b>	
H.J. Chung, S.W. Huh, A.Y. Polyakov, S. Nigam, Q. Li, J. Grim, M. Skowronski, E.R. Glaser, W.E. Carlos, J.A. Freitas and M.A. Fanton .....	625
<b>Accurate CsM<sup>+</sup> SIMS Aluminum Dopant Profiling in SiC</b>	
H.E. Smith, B.-H. Tsao and J. Scofield .....	629
<b>Results of SIMS, LTPL and Temperature-Dependent Hall Effect Measurements Performed on Al-Doped <math>\alpha</math>-SiC Substrates Grown by the M-PVT Method</b>	
S. Contreras, M. Zielinski, L. Konczewicz, C. Blanc, S. Juillaguet, R. Müller, U. Künecke, P. Wellmann and J. Camassel .....	633
<b>In-Diffusion, Trapping and Out-Diffusion of Deuterium in 4H-SiC Substrates</b>	
M.K. Linnarsson, M.S. Janson, U. Forsberg and E. Janzén .....	637

### 3.3.2 Transition Metals and Rare Earths

<b>Electronic Structure and Magnetic Properties of Transition Metal Doped Silicon Carbide in Different Polytypes</b>	
M.S. Miao and W.R.L. Lambrecht .....	641
<b>The Optical Admittance Spectroscopy of the Vanadium Donor and Acceptor Levels in Semi-Insulating 4H-SiC and 6H-SiC</b>	
W. Lee and M.E. Zvanut .....	647
<b>Luminescence and EPR Characterization of Vanadium Doped Semi-Insulating 4H SiC</b>	
E.N. Kalabukhova, D.V. Savchenko, S. Greulich-Weber, M.F. Bulanyi, S.A. Omelchenko, O.V. Khmelenko, A.A. Gorban and E.N. Mokhov .....	651

## **Co-doping of Er-Doped SiC with Oxygen – A Promising Way Towards Efficient 1540 nm Emission at Room Temperature?**

U. Gerstmann, E. Rauls, S. Sanna, Th. Frauenheim and H. Overhof ..... 655

## **Europium Induced Deep Levels in Hexagonal Silicon Carbide**

G. Pasold, F. Albrecht, C. Hülsen, R. Sielemann and W. Witthuhn ..... 659

## **Cathodoluminescence Measurements and Thermal Activation of Rare Earth Doped ( $Tb^{3+}$ , $Dy^{3+}$ and $Eu^{3+}$ ) a-SiC Thin Films Prepared by rf Magnetron Sputtering**

R. Weingärtner, O. Erlenbach, F. de Zela, A. Winnacker, I. Brauer and H.P. Strunk ..... 663

### **3.4 Surfaces and Interfaces**

#### **Hydrogen Nanochemistry Achieving Clean and Pre-Oxidized Silicon Carbide Surface Metallization**

P. Soukiassian, M.G. Silly, C. Radtke, H. Enriquez, M. D'angelo, V. Derycke, V.Yu. Aristov, F. Amy, Y.J. Chabal, P. Moras, M. Pedio, S. Gardonio, C. Ottaviani and P. Perfetti ..... 667

#### **Temperature Induced Phase Transformation on the 4H-SiC(11-20) Surface**

W.Y. Lee, S. Soubatch and U. Starke ..... 673

#### **SiC Pore Surfaces: Surface Studies of 4H-SiC(1-102) and 4H-SiC(-110-2)**

U. Starke, W.Y. Lee, C. Coletti, S.E. Saddow, R.P. Devaty and W.J. Choyke ..... 677

#### **Experimental Study of the Formation and Oxidation of the Sm/4H-SiC Surface Alloy**

M. Kildemo, U. Grossner, M. Juel, B. Samuelsen, B.G. Svensson and S. Raaen ..... 681

#### **Low Energy Ion Modification of 3C-SiC Surfaces**

Ch. Förster, R. Kosiba, G. Ecke, V. Cimalla, O. Ambacher and J. Pezoldt ..... 685

### **3.5 Fundamental Properties**

#### **Phonons in SiC from INS, IXS, and Ab-Initio Calculations**

D. Strauch, B. Dorner, A. Ivanov, M. Krisch, J. Serrano, A. Bosak, W.J. Choyke, B. Stojetz and M. Malorny ..... 689

#### **Infrared Reflectance Study of 3C-SiC Grown on Si by Chemical Vapor Deposition**

Z.C. Feng, C.W. Huang, W.Y. Chang, J. Zhao, C.C. Tin, W. Lu and W.E. Collins ..... 695

#### **Precise Determination of Thermal Expansion Coefficients Observed in 4H-SiC Single Crystals**

M. Nakabayashi, T. Fujimoto, M. Katsuno and N. Ohtani ..... 699

#### **Thermal Lens Technique for the Determination of SiC Thermo-optical Properties**

V. Anjos, M.J.V. Bell, E.A. de Vasconcelos, E.F. da Silva, Jr., A.A. Andrade, R.W.A. Franco, M.P.P. Castro, I.A. Esquef and R.T. Faria, Jr. ..... 703

#### **Wannier-Stark Ladder and Negative Differential Conductance in 4H-SiC**

V.I. Sankin and R. Yakimova ..... 707

### **3.6 Wafer Mapping**

#### **Characterization of SiC Wafers by Photoluminescence Mapping**

M. Tajima, E. Higashi, T. Hayashi, H. Kinoshita and H. Shiomi ..... 711

<b>Correlation between Room Temperature Photoluminescence and Resistivity in Semiinsulating Silicon Carbide</b>	717
S.K. Chanda, Y. Koshka and M. Yoganathan .....	717
<b>Simple, Calibrated Analysis and Mapping of SiC Wafer Defects by Birefringence Imaging</b>	721
S.-H. Park, M.J. Loboda and M.J. Spaulding .....	721
<b>SiC Substrate Doping Profiles Using Commercial Optical Scanners</b>	725
J.D. Caldwell, O.J. Glembocki, D.M. Hansen, G. Chung, K. Hobart and F. Kub .....	725
<b>Characterization of SiC Substrates Using X-Ray Rocking Curve Mapping</b>	729
M. Yoganathan, E. Emorhokpor, T. Kerr, A. Gupta, C.D. Tanner and I. Zwieback .....	729
<b>Microwave Dielectric Loss Characterization of Silicon Carbide Wafers</b>	733
T. Bogart, B. Everson, R. Gamble, E. Oslosky, D. Snyder, E. Furman, S. Perini and M. Lanagan .....	733

## Chapter 4. Porous SiC, SiC Nanoparticles and Nanowires

<b>Columnar Pore Growth in n-type 6H SiC</b>	739
Y. Ke, F. Yan, R.P. Devaty and W.J. Choyke .....	739
<b>A Comparison of Various Surface Finishes and the Effects on the Early Stages of Pore Formation during High Field Etching of SiC</b>	743
Y. Ke, C. Moisson, S. Gaan, R.M. Feenstra, R.P. Devaty and W.J. Choyke .....	743
<b>Brillouin Spectra of Porous p-Type 6H-SiC</b>	747
G.T. Andrews, C. Young, A. Polomska, M.J. Clouter, Y. Ke, R.P. Devaty and W.J. Choyke .....	747
<b>Columnar Morphology of Porous Silicon Carbide as a Protein-Permeable Membrane for Biosensors and Other Applications</b>	751
A.J. Rosenbloom, S. Nie, Y. Ke, R.P. Devaty and W.J. Choyke .....	751
<b>Novel Polycrystalline SiC Films Containing Nanoscale Through-Pores by Selective APCVD</b>	755
L. Chen, X.A. Fu, C.A. Zorman and M. Mehregany .....	755
<b>Sol-Gel Silicon Carbide for Photonic Applications</b>	759
B. Friedel and S. Greulich-Weber .....	759
<b>Formation, Morphology and Optical Properties of SiC Nanopowder</b>	763
T. Nychyporuk, O. Marty, J.M. Bluet, V. Lysenko, R. Perrin, G. Guillot and D. Barbier .....	763
<b>A Simple Method to Synthesize Nano-sized 3C-SiC Powder Using Hexamethyldisilane in a CVD Reactor</b>	767
A. Gupta and C. Jacob .....	767
<b>Fabrication and Electrical Transport Properties of CVD Grown Silicon Carbide Nanowires (SiC NWs) for Field Effect Transistor</b>	771
H.-K. Seong, S.-Y. Lee, H.-J. Choi, T.-H. Kim, N.-K. Cho, K.-S. Nahm and S.-K. Lee .....	771
<b>Thermodynamic Analysis of Synthetic Potentialities of the nSiC + SiO<sub>2</sub> Starting System: SiC Gas-Phase Transport Via Si(g) and CO(g)</b>	775
V.G. Sevastyanov, R.G. Pavelko, Yu.S. Ezhov and N.T. Kuznetsov .....	775
<b>Author Index</b>	1
<b>Keyword Index</b>	1

## **Part 2:**

### **Chapter 5. Processing of SiC**

#### **5.1 Implantation and Doping of SiC**

##### **Ion Implantation Processing and Related Effects in SiC**

B.G. Svensson, A. Hallén, J. Wong-Leung, M.S. Janson, M.K. Linnarsson, A.Yu. Kuznetsov, G. Alfieri, U. Grossner, E.V. Monakhov, H.K.-Nielsen, C. Jagadish and J. Grillenberger .....	781
--	-----

##### **Advances in Two-Dimensional Dopant Profiling and Imaging of 4H-SiC Devices**

M. Buzzo, M. Ciappa, M. Treu and W. Fichtner .....	787
--	-----

##### **Annealing Behavior of N<sup>+</sup>-Implantation-Induced Defects in SiC at Low Temperatures**

M. Satoh, T. Suzuki and S. Miyagawa .....	791
---	-----

##### **Impact of Annealing Temperature Ramps on the Electrical Activation of N<sup>+</sup> and P<sup>+</sup> Co-implanted SiC Layers**

S. Blanqué, R. Pérez, N. Mestres, S. Contreras, J. Camassel and P. Godignon .....	795
---	-----

##### **Impurity Concentration Dependence of Recrystallization Process of Phosphorus Implanted 4H-SiC(11-20)**

M. Satoh and T. Suzuki .....	799
------------------------------	-----

##### **Activation Treatment of Ion Implanted Dopants Using Hybrid Super RTA Equipment**

A. Kinoshita, J. Senzaki, M. Katou, S. Harada, M. Okamoto, S. Nishizawa, K. Fukuda, F. Morigasa, T. Endou, T. Isii and T. Yashima .....	803
---	-----

##### **Development and Investigation on EBAS-100 of 100 mm Diameter Wafer for 4H-SiC**

##### **Post Ion Implantation Annealing**

M. Shibagaki, M. Satoh, Y. Kurematsu, K. Numajiri, F. Watanabe, S. Haga, K. Miura, T. Suzuki and S. Miyagawa .....	807
--	-----

##### **Correlation between Current Transport and Defects in n<sup>+</sup>/p 6H-SiC Diodes**

M. Canino, A. Castaldini, A. Cavallini, F. Moscatelli, R. Nipoti and A. Poggi .....	811
---	-----

##### **Current Analysis of Ion Implanted p<sup>+</sup>/n 4H-SiC Junctions: Post-Implantation Annealing in Ar Ambient**

R. Nipoti, F. Bergamini, F. Moscatelli, A. Poggi, M. Canino and G. Bertuccio .....	815
--	-----

##### **Ion Implanted p<sup>+</sup>/n Diodes: Post-Implantation Annealing in a Silane Ambient in a Cold-Wall Low-Pressure CVD Reactor**

F. Bergamini, S.P. Rao, A. Poggi, F. Tamarri, S.E. Saddow and R. Nipoti .....	819
---	-----

##### **Laser Direct Write Doping and Metallization Fabrication of Silicon Carbide PIN Diodes**

Z. Tian, N.R. Quick and A. Kar .....	823
--------------------------------------	-----

##### **Extracting Activation and Compensation Ratio from Aluminum Implanted 4H-SiC by Modeling of Resistivity Measurements**

M. Rambach, L. Frey, A.J. Bauer and H. Ryssel .....	827
---	-----

##### **Variations in the Effects of Implanting Al at Different Concentrations into SiC**

K.A. Jones, T.S. Zheleva, P.B. Shah, M.A. Derenge, J.A. Freitas, G.J. Gerardi, R.D. Vispute, S. Hullavard and S. Dar .....	831
--	-----

<b>Effect of Surface Orientation and Off-Angle on Surface Roughness and Electrical Properties of p-type Impurity Implanted 4H-SiC Substrate after High Temperature Annealing</b>	
A. Kinoshita, M. Katou, M. Kawasaki, K. Kojima, K. Fukuda, K. Arai, F. Morigasa, T. Endou, T. Isii and T. Yashima .....	835
<b>Post-Implantation Annealing in a Silane Ambient using Hot-Wall CVD</b>	
S. Rao, F. Bergamini, R. Nipoti, A.M. Hoff, E. Oborina and S.E. Saddow .....	839
<b>Kick-Out Phenomena in Epitaxially Boron- and Aluminum-Doped 4H-SiC During Implantation and Annealing Processes</b>	
Y. Negoro, T. Kimoto, H. Matsunami and G. Pensl .....	843
<b>Observation of Thermal-Annealing Evolution of Defects in Ion-Implanted 4H-SiC by Luminescence</b>	
J.A. Freitas, Jr., K.A. Jones, M.A. Derenge, R.D. Vispute and S. Hullavard .....	847
<b>High Dose High Temperature Ion Implantation of Ge into 4H-SiC</b>	
Th. Kups, P. Weih, M. Voelskow, W. Skorupa and J. Pezoldt .....	851
<b>Hydrogen-Induced Blistering of SiC: The Role of Post-Implant Multi-Step Annealing Sequences</b>	
G. Malouf, B. Poust, S. Hayashi, G. Yoshizawa and M.S. Goorsky .....	855
<b>5.2 Contacts</b>	
<b>5.2.1 Ohmic Contacts</b>	
<b>An Approach to Improving the Morphology and Reliability of n-SiC Ohmic Contacts to SiC Using Second-Metal Contacts</b>	
M.H. Ervin, K.A. Jones, U. Lee, T. Das and M.C. Wood .....	859
<b>Ni Graphite Intercalated Compounds in Ohmic Contact Formation on SiC</b>	
W. Lu, J.A. Michel, C.M. Lukehart, W.E. Collins and W.C. Mitchel .....	863
<b>Ohmic Contact for C-face n-type 4H-SiC with Reduced Graphite Precipitation</b>	
Y. Maeyama, K. Nishikawa, Y. Fukuda, M. Shimizu, M. Sato, J. Ono and H. Iwakuro .....	867
<b>Structural Properties of Titanium-Nickel Films on Silicon Carbide Following High Temperature Annealing</b>	
K.V. Vassilevski, I.P. Nikitina, A.B. Horsfall, N.G. Wright, C.M. Johnson, R.K. Malhan and T. Yamamoto.....	871
<b>Die Bonding Issues on Silicon Carbide Diodes</b>	
S.-Y. Lee, J.-S. Lee, T.-H. Kim, S.-Y. Choi, H.-J. Kim, W. Bahng, N.-K. Kim and S.-K. Lee .....	875
<b>Composite Ohmic Contacts to SiC</b>	
A.V. Adedeji, A.C. Ahyi, J.R. Williams, M.J. Bozack, S.E. Mohney, B. Liu and J.D. Scofield .....	879
<b>Tantalum-Ruthenium Diffusion Barriers for Contacts to SiC</b>	
S.H. Wang, O. Arnold, C.M. Eichfeld, S.E. Mohney, A.V. Adedeji and J.R. Williams .....	883
<b>Investigation of TiW Contacts to 4H-SiC Bipolar Junction Devices</b>	
H.-S. Lee, M. Domeij, C.-M. Zetterling, M. Östling and J. Lu .....	887
<b>Characterization of Ti/Al Ohmic Contacts to p-Type 4H-SiC Using Cathodoluminescence and Auger Electron Spectroscopies</b>	
M. Gao, S.P. Tumakha, T. Onishi, S. Tsukimoto, M. Murakami and L.J. Brillson .....	891

## **Ohmic Contacts to p-Type Epitaxial and Implanted 4H-SiC**

J. Crofton, J.R. Williams, A.V. Adedeji, J.D. Scofield, S. Dhar, L.C. Feldman and M.J. Bozack .....	895
---	-----

## **Ohmic Contacts on p-Type SiC Using Al/C Films**

W. Lu, G.R. Landis, W.E. Collins and W.C. Mitchel .....	899
---	-----

## **Ti/AlNi/W and Ti/Ni<sub>2</sub>Si/W Ohmic Contacts to p-Type SiC**

B.-H. Tsao, J. Lawson and J. Scofield .....	903
---	-----

### **5.2.2 Schottky Contacts**

#### **Nanoscale Deep Level Defect Correlation with Schottky Barriers in 4H-SiC/Metal Diodes**

S. Tumakha, L.M. Porter, D.J. Ewing, Q. Wahab, X.Y. Ma, T.S. Sudarshan and L.J. Brillson .....	907
--	-----

#### **A Study of Inhomogeneous Schottky Diodes on n-type 4H-SiC**

D.J. Ewing, Q. Wahab, S. Tumakha, L.J. Brillson, X.Y. Ma, T.S. Sudarshan and L.M. Porter .....	911
--	-----

#### **Formation and Properties of Schottky Diodes on 4H-SiC after High Temperature Annealing with Graphite Encapsulation**

Y. Wang, M.K. Mikhov and B.J. Skromme .....	915
---	-----

#### **Diffusion Welding Techniques for Power SiC Schottky Packaging**

O. Korolkov, T. Rang, A. Syrkin and V. Dmitriev .....	919
---	-----

#### **Evaluation of Schottky Barrier Height of Al, Ti, Au, and Ni Contacts to 3C-SiC**

M. Satoh and H. Matsuo .....	923
------------------------------	-----

#### **Comparison of Electrical Characteristics of 4H-SiC(0001) and (000-1) Schottky Barrier Diodes**

T. Nakamura, T. Miyanagi, I. Kamata and H. Tsuchida .....	927
---	-----

#### **High Temperature Operation of Silicon Carbide Schottky Diodes with Recoverable Avalanche Breakdown**

K. Vassilevski, I. Nikitina, P. Bhatnagar, A. Horsfall, N. Wright, A.G. O'Neill, M. Uren, K. Hilton, A. Munday, A. Hydes and C.M. Johnson .....	931
---	-----

### **5.3 Oxides and Other Dielectrics**

#### **Si/SiO<sub>2</sub> and SiC/SiO<sub>2</sub> Interfaces for MOSFETs – Challenges and Advances**

S.T. Pantelides, S. Wang, A. Franceschetti, R. Buczko, M. Di Ventra, S.N. Rashkeev, L. Tsetseris, M.H. Evans, I.G. Batyrev, L.C. Feldman, S. Dhar, K. McDonald, R.A. Weller, R.D. Schrimpf, D.M. Fleetwood, X.J. Zhou, J.R. Williams, C.C. Tin, G.Y. Chung, T. Isaacs-Smith, S.R. Wang, S.J. Pennycook, G. Duscher, K. van Benthem and L.M. Porter .....	935
--	-----

#### **Nitrogen and Hydrogen Induced Trap Passivation at the SiO<sub>2</sub>/4H-SiC Interface**

S. Dhar, S. Wang, A.C. Ahyi, T. Isaacs-Smith, S.T. Pantelides, J.R. Williams and L.C. Feldman .....	949
---	-----

#### **Impact of Dislocations on Gate Oxide in SiC MOS Devices and High Reliability ONO Dielectrics**

S. Tanimoto .....	955
-------------------	-----

#### **High Channel Mobility 4H-SiC MOSFETs**

E.Ö. Sveinbjörnsson, G. Gudjonsson, F. Allerstam, H.Ö. Ólafsson, P.-Å. Nilsson, H. Zirath, T. Rödle and R. Jos .....	961
--	-----

<b>Improved 4H-SiC MOS Interfaces Produced via Two Independent Processes: Metal Enhanced Oxidation and 1300°C NO Anneal</b>	
M.K. Das, B.A. Hull, S. Krishnaswami, F. Husna, S. Haney, A. Lelis, C.J. Scozzie and J.D. Scofield .....	967
<b>Characterization of 4H-SiC MOSFETs with NO-Annealed CVD Oxide</b>	
H. Yano, T. Hatayama, Y. Uraoka and T. Fuyuki .....	971
<b>Investigation of SiO<sub>2</sub>-SiC Interface by High-Resolution Transmission Electron Microscope</b>	
S. Dimitrijev, J. Han and J. Zou .....	975
<b>Interfacial Properties of SiO<sub>2</sub> Grown on 4H-SiC: Comparison between N<sub>2</sub>O and wet O<sub>2</sub> Oxidation Ambient</b>	
A. Poggi, F. Moscatelli, A. Scorzoni, G. Marino, R. Nipoti and M. Sanmartin .....	979
<b>Effect of Reactive-Ion Etching on Thermal Oxide Properties on 4H-SiC</b>	
K. Matocha, C. Cowen, R. Beaupre and J. Tucker .....	983
<b>Improved Dielectric and Interface Properties of 4H-SiC MOS Structures Processed by Oxide Deposition and N<sub>2</sub>O Annealing</b>	
T. Kimoto, H. Kawano, M. Noborio, J. Suda and H. Matsunami .....	987
<b>Nitrogen Implantation – An Alternative Technique to Reduce Traps at SiC/SiO<sub>2</sub>-Interfaces</b>	
F. Ciobanu, T. Frank, G. Pensl, V. Afanas'ev, S. Shamuilia, A. Schöner and T. Kimoto .....	991
<b>Process-Dependent Charges and Traps in Dielectrics on SiC</b>	
B. Krishnan, H. Das, Y. Koshka, I. Sankin, P.A. Martin and M.S. Mazzola .....	995
<b>Low-Temperature Post-Oxidation Annealing Using Atomic Hydrogen Radicals Generated by High-Temperature Catalyzer for Improvement in Reliability of Thermal Oxides on 4H-SiC</b>	
J. Senzaki, A. Shimozato and K. Fukuda .....	999
<b>Off-Angle Dependence of Characteristics of 4H-SiC-Oxide Interfaces</b>	
Y. Hijikata, H. Yaguchi, S. Yoshida, Y. Takata, K. Kobayashi, H. Nohira and T. Hattori .....	1003
<b>On Separating Oxide Charges and Interface Charges in 4H-SiC Metal-Oxide-Semiconductor Devices</b>	
D.B. Habersat, A.J. Lelis, G. Lopez, J.M. McGarrity and F.B. McLean .....	1007
<b>Observation of Deep-Level Centers in 4H-Silicon Carbide Metal Oxide Semiconductor Field Effect Transistors by Spin Dependent Recombination</b>	
M.S. Dautrich, P.M. Lenahan and A.J. Lelis .....	1011
<b>Forming Gas Annealing of the Carbon P<sub>b</sub>C Center in Oxidized Porous 3C- and 4H-SiC: An EPR Study</b>	
J.L. Cantin and H.J. von Bardeleben .....	1015
<b>Where Would the Electronic States of a Small Graphite-Like Carbon Island Contribute to the SiC/SiO<sub>2</sub> Interface State Density Distribution?</b>	
C. Thill, J. Knaup, P. Deák, T. Frauenheim and W.J. Choyke .....	1019
<b>Scanning Tunneling Spectroscopy of Oxidized 6H-SiC Surfaces</b>	
S. Nie and R.M. Feenstra .....	1023
<b>Ellipsometric and XPS Studies of 4H-SiC / SiO<sub>2</sub> Interfaces, and Sacrificial Oxide Stripped 4H-SiC Surfaces</b>	
O.J. Guy, L. Chen, G. Pope, K.S. Teng, T. Maffei, S.P. Wilks, P.A. Mawby, T. Jenkins, A. Brieva and D.J. Hayton .....	1027
<b>Real Time Observation of SiC Oxidation Using an In-Situ Ellipsometer</b>	
K. Kakubari, R. Kuboki, Y. Hijikata, H. Yaguchi and S. Yoshida .....	1031

<b>Fast Non-Contact Dielectric Characterizations for SiC MOS Processing</b>	
A.M. Hoff and E. Oborina .....	1035
<b>High Temperature Reliability of SiC n-MOS Devices up to 630 °C</b>	
R.N. Ghosh, R. Loloe, T. Isaacs-Smith and J.R. Williams .....	1039
<b>High Inversion Channel Mobility of 4H-SiC MOSFETs Fabricated on C(000-1) Epitaxial Substrate with Vicinal (Below 1°) Off-Angle</b>	
K. Fukuda, M. Kato, S. Harada and K. Kojima .....	1043
<b>PECVD Deposited TEOS for Field-Effect Mobility Improvement in 4H-SiC MOSFETs on the (0001) and (11-20) Faces</b>	
A. Pérez-Tomás, P. Godignon, J. Camassel, N. Mestres and V. Soulière .....	1047
<b>Process Optimisation for &lt;11-20&gt; 4H-SiC MOSFET Applications</b>	
C. Blanc, D. Tournier, P. Godignon, D.J. Bring, V. Soulière and J. Camassel .....	1051
<b>Determination of the Temperature and Field Dependence of the Interface Conductivity Mobility in 4H-SiC/SiO<sub>2</sub></b>	
G. Pennington, S. Potbhare, N. Goldsman, D. Habersat and A. Lelis .....	1055
<b>Modelling of the Anomalous Field-Effect Mobility Peak of O-Ta<sub>2</sub>Si/4H-SiC High-<i>k</i> MOSFETs Measured in Strong Inversion</b>	
A. Pérez-Tomás, M. Vellvehí, N. Mestres, J. Millán, P. Vennegues and J. Stoemenos .....	1059
<b>Gamma Irradiation Effects on 4H-SiC MOS Capacitors and MOSFETs</b>	
A.C. Ahyi, S.R. Wang and J.R. Williams .....	1063
<b>High Temperature Annealing Study of Al<sub>2</sub>O<sub>3</sub> Deposited by ALCVD on n-Type 4H-SiC</b>	
M. Avice, U. Grossner, O. Nilsen, J.S. Christensen, H. Fjellvåg and B.G. Svensson .....	1067
<b>Experimental and First-Principles Studies of the Band Alignment at the HfO<sub>2</sub>/4H-SiC (0001) Interface</b>	
C.M. Tanner, J. Choi and J.P. Chang .....	1071
<b>Structural and Morphological Properties of Ultrathin HfO<sub>2</sub> Dielectrics on 4H-SiC (0001)</b>	
C.M. Tanner, J. Lu, H.-O. Blom and J.P. Chang .....	1075
<b>Low Temperature Deposition of HfO<sub>2</sub> Gate Insulator on SiC by Metalorganic Chemical Vapor Deposition</b>	
S. Hino, T. Hatayama, N. Miura, T. Ozeki and E. Tokumitsu .....	1079
<b>Electrical Properties of the La<sub>2</sub>O<sub>3</sub>/4H-SiC Interface Prepared by Atomic Layer Deposition Using La(iPrCp)<sub>3</sub> and H<sub>2</sub>O</b>	
J.H. Moon, D.I. Eom, S.Y. No, H.K. Song, J.H. Yim, H.J. Na, J.B. Lee and H.J. Kim .....	1083
<b>Theoretical Study of an Effective Field Plate Termination for SiC Devices Based on High-<i>k</i> Dielectrics</b>	
M. Brezeanu, M. Badila, G. Brezeanu, F. Udrea, C. Boianceanu, G.A.J. Amaralunga and K. Zekentes .....	1087

## 5.4 Chemical-Mechanical Polishing of SiC

<b>Preparation and Evaluation of Damage Free Surfaces on Silicon Carbide</b>	
W.J. Everson, V.D. Heydemann, R.D. Gamble, D.W. Snyder, G. Goda, M. Skowronski, J. Grim, E. Berkman, J.M. Redwing and J.D. Acord .....	1091
<b>Selectivity and Residual Damage of Colloidal Silica Chemi-mechanical Polishing of Silicon Carbide</b>	
J.R. Grim, M. Skowronski, W.J. Everson and V.D. Heydemann .....	1095

<b>Augmented CMP Techniques for Silicon Carbide</b>	.....	1099
P. Kuo and I. Currier .....		

## 5.5 Micromachining and MEMS

<b>Characterization of Low Stress, Undoped LPCVD Polycrystalline SiC Films for MEMS Applications</b>	.....	
J. Dunning, X.A. Fu, M. Mehregany and C.A. Zorman .....		1103
<b>Mechanical Testing of Flexible Silicon Carbide Interconnect Ribbons</b>	.....	
R. Panday, X.A. Fu, S. Rajgopal, T. Lisby, S.A. Nikles, K. Najafi and M. Mehregany .....		1107
<b>Micromachining of Novel SiC on Si Structures for Device and Sensor Applications</b>	.....	
Ch. Foerster, V. Cimalla, M. Stubenrauch, C. Rockstuhl, K. Brueckner, M. Hein, J. Pezoldt and O. Ambacher .....		1111
<b>Deep Reactive Ion Etching (DRIE) of High Aspect Ratio SiC Microstructures using a Time-Multiplexed Etch-Passivate Process</b>	.....	
L.J. Evans and G.M. Beheim .....		1115
<b>Via Hole Formation in Silicon Carbide by Laser Micromachining</b>	.....	
K. Zekentes, I. Zergioti, A. Klini and G. Constantinidis .....		1119
<b>Development of a Microstrip SiC MMIC Process</b>	.....	
M. Südow, K. Andersson, N. Billström, J. Nilsson, P.-Å. Nilsson, N. Rorsman, J. Ståhl and H. Zirath .....		1123

## Chapter 6. SiC Devices

### 6.1 Overviews

<b>Energy Efficiency: The Commercial Pull for SiC Devices</b>	.....	
J.W. Palmour .....		1129
<b>SiC Device Applications: Identifying and Developing Commercial Applications</b>	.....	
J.M. Hancock .....		1135
<b>Developments in Hybrid Si – SiC Power Modules</b>	.....	
G. Skibinski, D. Braun, D. Kirschnik and R. Lukaszewski .....		1141

### 6.2 Unipolar Devices

#### 6.2.1 Schottky Diodes

<b>Almost Ideal Thermionic-Emission Properties of Ti-Based 4H-SiC Schottky Barrier Diodes</b>	.....	
D. Stephani, R. Schoerner, D. Peters and P. Friedrichs .....		1147
<b>Electrothermal Issues in 4H-SiC 600 V Schottky Diodes in Forward Mode: Experimental Characterization, Numerical Simulations and Analytical Modeling</b>	.....	
A. Irace, V. d'Alessandro, G. Breglio, P. Spirito, A. Bricconi, R. Carta, D. Raffo and L. Merlin .....		1151

## **A Surge Current Stable and Avalanche Rugged SiC Merged pn Schottky Diode Blocking 600V Especially Suited for PFC Applications**

M. Treu, R. Rupp, C.S. Tai, P. Blaschitz, J. Hilsenbeck, H. Brunner, D. Peters, R. Elpelt and T. Reimann ..... 1155

## **Performance Comparison of 1.5kV 4H-SiC Buried Channel and Lateral Channel JBS Rectifiers**

L. Zhu, T.P. Chow, K.A. Jones, C. Scozzie and A. Agarwal ..... 1159

### **4.5 kV-8 A SiC-Schottky Diodes / Si-IGBT Modules**

D. Tournier, P. Waind, P. Godignon, L. Coulbeck, J. Millán and R. Bassett ..... 1163

## **Correlation between Leakage Current and Ion-Irradiation Induced Defects in 4H-SiC Schottky Diodes**

V. Raineri, F. Roccaforte, S. Libertino, A. Ruggiero, V. Massimino and L. Calcagno ..... 1167

## **Design and Analysis of a Dual-Step Field-Plate Terminated 4H-SiC Schottky Diode Using SiO<sub>2</sub>/High-K Dielectric Stack**

A. Kumta, Rusli and C.-C. Tin ..... 1171

## **Fabrication of 4H-SiC Floating Junction Schottky Barrier Diodes (Super-SBDs) and Their Electrical Properties**

C. Ota, J. Nishio, T. Hatakeyama, T. Shinohe, K. Kojima, S. Nishizawa and H. Ohashi ..... 1175

## **Optimization of a SiC Super-SBD Based on Scaling Properties of Power Devices**

T. Hatakeyama, C. Ota, J. Nishio and T. Shinohe ..... 1179

### **6.2.2 JFETs and MESFETs**

## **Fast Switching (41 MHz), 2.5 mΩ·cm<sup>2</sup>, High Current 4H-SiC VJFETs for High Power and High Temperature Applications**

L. Cheng, J.R.B. Casady, M.S. Mazzola, V. Bondarenko, R.L. Kelley, I. Sankin, J.N. Merrett and J.B. Casady ..... 1183

## **10 kV, 87 mΩcm<sup>2</sup> Normally-Off 4H-SiC Vertical Junction Field-Effect Transistors**

Y. Li, P. Alexandrov, J. Zhang, L.X. Li and J.H. Zhao ..... 1187

## **Design, Fabrication and Application of 4H-SiC Trenched-and-Implanted Vertical JFETs**

J.H. Zhao, P. Alexandrov, Y. Li, L. Li, K. Sheng and R. Lebron-Velilla ..... 1191

## **Analytical Modelling of I-V Characteristics for 4H-SiC Enhancement Mode VJFET**

P. Bhatnagar, A.B. Horsfall, N.G. Wright, C.M. Johnson, K.V. Vassilevski and A.G. O'Neill ..... 1195

## **Design Considerations of a New 4H-SiC Enhancement-Mode Lateral Channel Vertical JFET for Low-Loss Switching Operation**

Y.C. Choi, H.-Y. Cha, L.F. Eastman and M.G. Spencer ..... 1199

## **Low On-Resistance in 4H-SiC RESURF JFETs Fabricated with Dry Process for Implantation Metal Mask**

T. Masuda, K. Fujikawa, K. Shibata, H. Tamaso, S. Hatsukawa, H. Tokuda, A. Saegusa, Y. Namikawa and H. Hayashi ..... 1203

## **SiC Smart Power JFET Technology for High-Temperature Applications**

I. Sankin, V. Bondarenko, R. Kelley and J.B. Casady ..... 1207

## **Inherently Safe Resonant Reset Forward Converter Using a Bias-Enhanced SiC JFET**

R. Kelley, T. Brignac, M. Mazzola and J.B. Casady ..... 1211

<b>Current Sensing for SiC Power Devices</b>	D. Tournier, M. Vellvehi, P. Godignon, J. Montserrat, D. Planson and F. Sarrus .....	1215
<b>Fabrication of 700V SiC-SIT with Ultra-Low On-Resistance of <math>1.01\text{m}\Omega\cdot\text{cm}^2</math></b>	Y. Tanaka, K. Yano, M. Okamoto, A. Takatsuka, K. Fukuda, M. Kasuga, K. Arai and T. Yatsuo .....	1219
<b>RF and DC Characterization of Self-Aligned L-Band 4H-SiC Static Induction Transistors</b>	J.N. Merrett, I. Sankin, V. Bonderenko, C.E. Smith, D. Kajfez and J.R.B. Casady .....	1223
<b>SiC MESFET with a Double Gate Recess</b>	P.-Å. Nilsson, N. Rorsman, M. Südow, K. Andersson, H. Hjelmgren and H. Zirath .....	1227
<b>High Power High Efficiency Lateral Epitaxy MESFETs in Silicon Carbide</b>	A.O. Konstantinov, J.-O. Svedberg, I. Ray, C.I. Harris, C. Hallin and B.-O. Larsson .....	1231
<b>RF Characteristics of a Fully Ion-Implanted MESFET on a Bulk Semi-Insulating 4H-SiC Substrate</b>	M. Ogata, S. Katakami, S. Ono and M. Arai .....	1235
<b>High-Frequency SiC MESFETs with Silicon Dioxide/Silicon Nitride Passivation</b>	K. Matocha, E. Kaminsky, A. Vertiatchikh and J. Casady .....	1239
<b>Double Gate 180V-128mA/mm SiC-MESFET for Power Switch Applications</b>	D. Tournier, M. Vellvehi, P. Godignon, X. Jordà and J. Millán .....	1243
<b>The Role of Residual Source/Drain Implant Damage Traps on SiC MESFET Drain I-V Characteristics</b>	J. Adjaye, M.S. Mazzola and A.V. Los .....	1247
<b>Time Domain and Frequency Analysis of Random Telegraph Signal and the Contributions of G-R Centres to I-V Instabilities in 4H-SiC MESFETs</b>	M. Trabelsi, N. Sghaier, J.M. Bluet, N. Yacoubi, G. Guillot and C. Brylinski .....	1251

### 6.2.3 MOSFETs

<b>SiC Power MOSFETs – Status, Trends and Challenges</b>	D. Peters, R. Schoerner, P. Friedrichs and D. Stephani .....	1255
<b>Development of <math>8\text{ m}\Omega\cdot\text{cm}^2</math>, 1.8 kV 4H-SiC DMOSFETs</b>	S.-H. Ryu, S. Krishnaswami, B. Hull, B. Heath, M. Das, J. Richmond, A. Agarwal, J. Palmour and J. Scofield .....	1261
<b>4H-SiC DMOSFETs Processed Using Graphite Capped Implant Activation Anneal</b>	J.B. Fedison, C.S. Cowen, J.L. Garrett, E.T. Downey, J.W. Kretchmer, R.L. Klinger, H.C. Peters, J.B. Tucker, K.S. Matocha, L.B. Rowland and S.D. Arthur .....	1265
<b>Optimum Design of Short-Channel 4H-SiC Power DMOSFETs</b>	A. Saha and J.A. Cooper .....	1269
<b>Realization of Large Area Vertical 3C-SiC MOSFET Devices</b>	A. Schöner, M. Bakowski, P. Ericsson, H. Strömberg, H. Nagasawa and M. Abe .....	1273
<b>High Power-Density 4H-SiC RF MOSFETs</b>	G. Gudjónsson, F. Allerstam, H.Ö. Ólafsson, P.-Å. Nilsson, H. Hjelmgren, K. Andersson, E.Ö. Sveinbjörnsson, H. Zirath, T. Rödle and R. Jos .....	1277
<b>4.3 <math>\text{m}\Omega\text{cm}^2</math>, 1100 V 4H-SiC Implantation and Epitaxial MOSFET</b>	S. Harada, M. Kato, M. Okamoto, T. Yatsuo, K. Fukuda and K. Arai .....	1281

<b>Fabrication and Performance of 1.2 kV, 12.9 m<math>\Omega</math>cm<sup>2</sup> 4H-SiC Epilayer Channel MOSFET</b>	
Y. Tarui, T. Watanabe, K. Fujihira, N. Miura, Y. Nakao, M. Imaizumi, H. Sumitani, T. Takami, T. Ozeki and T. Oomori .....	1285
<b>Switching Characteristics of SiC-MOSFET and SBD Power Modules</b>	
M. Imaizumi, Y. Tarui, S. Kinouchi, H. Nakatake, Y. Nakao, T. Watanabe, K. Fujihira, N. Miura, T. Takami and T. Ozeki .....	1289
<b>Characterization of 4H-SiC MOSFETs Formed on the Different Trench Sidewalls</b>	
H. Nakao, H. Mikami, H. Yano, T. Hatayama, Y. Uraoka and T. Fuyuki .....	1293
<b>The Characteristics of MOSFETs Fabricated on the Trench Sidewalls of Various Faces Using 4H-SiC (11-20) Substrates</b>	
H. Fujisawa, T. Tsuji and M. Nishiura .....	1297
<b>Fabrication of 4H-SiC p-channel MOSFET with High Channel Mobility</b>	
M. Okamoto, M. Tanaka, T. Yatsuo and K. Fukuda .....	1301
<b>Reduction of On-Resistance in 4H-SiC Multi-RESURF MOSFETs</b>	
M. Noborio, Y. Negoro, J. Suda and T. Kimoto .....	1305
<b>Fabrication of 4H-SiC DIMOSFETs by High-Temperature (&gt;1400°C) Rapid Thermal Oxidation and Nitridation Using Cold-Wall Oxidation Furnace</b>	
R. Kosugi, K. Suzuki, K. Takao, Y. Hayashi, T. Yatsuo, K. Fukuda, H. Ohashi and K. Arai .....	1309
<b>A Study on the Reliability and Stability of High Voltage 4H-SiC MOSFET Devices</b>	
S. Krishnaswami, S.-H. Ryu, B. Heath, A. Agarwal, J. Palmour, B. Geil, A. Lelis and C. Scozzie .....	1313
<b>Bias Stress-Induced Threshold-Voltage Instability of SiC MOSFETs</b>	
A.J. Lelis, D. Habersat, G. Lopez, J.M. McGarrity, F.B. McLean and N. Goldsman .....	1317
<b>Using a First Principles Coulomb Scattering Mobility Model for 4H-SiC MOSFET Device Simulation</b>	
S. Potbhare, G. Pennington, N. Goldsman, A. Lelis, D. Habersat, F.B. McLean and J.M. McGarrity .....	1321
<b>Optimisation of 4H-SiC MOSFET Structures for Logic Applications</b>	
A.B. Horsfall, C.H.A. Prentice, P. Tappin, P. Bhatnagar, N.G. Wright, K.V. Vassilevski and I.P. Nikitina .....	1325
<b>6.3 Bipolar Devices</b>	
<b>6.3.1 Diodes</b>	
<b>Evolution of Drift-Free, High Power 4H-SiC PiN Diodes</b>	
M.K. Das, J.J. Sumakeris, B.A. Hull and J. Richmond .....	1329
<b>Measurements of Breakdown Field and Forward Current Stability in 3C-SiC pn Junction Diodes Grown on Step-Free 4H-SiC</b>	
P.G. Neudeck, D.J. Spry and A.J. Trunek .....	1335
<b>High-Temperature (up to 800 K) Operation of 6-kV 4H-SiC Junction Diodes</b>	
M.E. Levenshtein, P.A. Ivanov, M.S. Boltovet, V.A. Krivutsa, J.W. Palmour, M.K. Das and B.A. Hull .....	1339
<b>About the Nature of Recombination Current in 4H-SiC pn Structures</b>	
A.M. Strel'chuk, A.V. Mashichev, A.A. Lebedev, A.N. Volkova and K. Zekentes .....	1343

<b>Charge Induced in 6H-SiC PN Diodes by Irradiation of Oxygen Ion Microbeams</b>	
T. Ohshima, T. Satoh, M. Oikawa, S. Onoda, T. Hirao and H. Itoh .....	1347
<b>Demonstration of a 4H SiC Betavoltaic Cell</b>	
M.V.S. Chandrashekhar, C.I. Thomas, H. Li, M.G. Spencer and A. Lal .....	1351
<b>High Current 6 kV 4H-SiC PiN Diodes for Power Module Switching Applications</b>	
B.A. Hull, M.K. Das, J.T. Richmond, B. Heath, J.J. Sumakeris, B. Geil and C.J. Scozzie .....	1355
<b>Dynamic Characteristics of 4H-SiC pin Diode on (000-1)C-Face with Small Forward Degradation</b>	
K. Nakayama, Y. Sugawara, R. Ishii, H. Tsuchida, T. Miyanagi, I. Kamata and T. Nakamura .....	1359
<b>Improving Switching Characteristics of 4H-SiC Junction Rectifiers Using Epitaxial and Implanted Anodes with Epitaxial Refill</b>	
P.A. Losee, C. Li, R.J. Kumar, T.P. Chow, I.B. Bhat, R.J. Gutmann and R.E. Stahlbush .....	1363
<b>Characteristics and Ionization Coefficient Extraction of 1kV 4H-SiC Implanted Anode PiN Rectifiers with Near Ideal Performance Fabricated Using AlN Capped Annealing</b>	
L. Zhu, P.A. Losee, T.P. Chow, K.A. Jones, C. Scozzie, M.H. Ervin, P.B. Shah, M.A. Derenge, R.D. Vispute, T. Venkatesan and A. Agarwal .....	1367
<b>Demonstration of High-Voltage 4H-SiC Bipolar RF Power Limiter</b>	
M. Su, X. Xin, L.X. Li and J.H. Zhao .....	1371
<b>Investigation of Packaged High-Voltage 4H SiC pin Diodes in the 20-700 °C Temperature Range</b>	
M.S. Boltovets, V.V. Basanets, N. Camara, V.A. Krivutsa and K. Zekentes .....	1375
<b>CM-Wave Modulator with High-Voltage 4H SiC pin Diodes</b>	
M.S. Boltovets, V.V. Basanets, A.V. Zorenko, V.A. Krivutsa, N. Camara, V.O. Orechovskij, V.I. Simonchuk and K. Zekentes .....	1379
<b>Numerical Investigation of SiC Devices Performance Considering the Incomplete Dopant Ionization</b>	
A. Udal and E. Velmre .....	1383
<b>High Power Photoconductive Switch of 4H-SiC with Damage-Free Electrodes by Using n<sup>+</sup>-GaN Subcontact Layer</b>	
K. Zhu, G. Li, D. Johnstone, Y. Fu, J. Leach, B. Ganguly, C.W. Litton and H. Morkoç .....	1387

### 6.3.2 Transistors and Thyristors

<b>Advances in SiC GTO Development and Its Applications</b>	
Y. Sugawara .....	1391
<b>A 1cm × 1cm, 5kV, 100A, 4H-SiC Thyristor Chip for High Current Modules</b>	
A.K. Agarwal, S. Krishnaswami, B. Damsky, J. Richmond, C. Capell, S.-H. Ryu and J.W. Palmour .....	1397
<b>Simulation of High-Voltage Injection-Enhanced 4H-SiC N-Channel IGBTs with Forward Drop Approaching that of a PiN Junction Rectifier</b>	
L. Zhu and T.P. Chow .....	1401
<b>Simulations of 10 kV Trench Gate IGBTs on 4H-SiC</b>	
Q. Zhang, S.-H. Ryu, C. Jonas, A. Agarwal and J. Palmour .....	1405

<b>Influence of Basal Plane Dislocation Induced Stacking Faults on the Current Gain in SiC BJTs</b>	
A. Agarwal, S. Krishnaswami, J. Richmond, C. Capell, S.-H. Ryu, J. Palmour, B. Geil, D. Katsis, C. Scozzie and R. Stahlbush .....	1409
<b>First Demonstration of 2.1 kW Output Power at 425 MHz Using 4H-SiC RF Power BJTs</b>	
A. Agarwal, F. Husna, J. Haley, H. Bartlow, B. McCalpin, S. Krishnaswami, C. Capell, S.-H. Ryu and J.W. Palmour .....	1413
<b>1836 V, 4.7 mΩ·cm<sup>2</sup> High Power 4H-SiC Bipolar Junction Transistor</b>	
J. Zhang, J. Wu, P. Alexandrov, T. Burke, K. Sheng and J.H. Zhao .....	1417
<b>4H-SiC Bipolar Transistors with UHF and L-Band Operation</b>	
I. Perez-Wurfl, F. Zhao, C.-F. Huang, J. Torvik and B. Van Zeghbroeck .....	1421
<b>Current Gain Dependence on Emitter Width in 4H-SiC BJTs</b>	
M. Domeij, H.-S. Lee, C.-M. Zetterling, M. Östling and A. Schöner .....	1425
<b>Optimization of the Specific On-Resistance of 4H-SiC BJTs</b>	
S. Balachandran, T.P. Chow and A. Agarwal .....	1429
<b>Performance Assessment of 4H-SiC Bipolar Junction Transistors and Insulated Gate Bipolar Transistors</b>	
S. Balachandran, T.P. Chow and A. Agarwal .....	1433
<b>High Temperature Characterization of 4H-SiC Bipolar Junction Transistors</b>	
S. Krishnaswami, A. Agarwal, J. Richmond, C. Capell, S.-H. Ryu, J. Palmour, B. Geil, D. Katsis and C. Scozzie .....	1437
<b>Analysis of the Effect of Temperature on Base Current Gain in Power 4H-SiC BJTs</b>	
P.A. Ivanov, M.E. Levinshtein, A.K. Agarwal, S. Krishnaswami and J.W. Palmour .....	1441
<b>400 Watt Boost Converter Utilizing Silicon Carbide Power Devices and Operating at 200°C Baseplate Temperature</b>	
J. Richmond, S.-H. Ryu, S. Krishnaswami, A. Agarwal, J. Palmour, B. Geil, D. Katsis and C. Scozzie .....	1445
<b>Device Options and Design Considerations for High-Voltage (10-20 kV) SiC Power Switching Devices</b>	
Y. Sui, G.G. Walden, X. Wang and J.A. Cooper .....	1449
<b>Novel Power Si/4H-SiC Heterojunction Tunneling Transistor (HETT)</b>	
T. Hayashi, Y. Shimoida, H. Tanaka, S. Yamagami, S. Tanimoto and M. Hoshi .....	1453
 <b>6.4 Sensors and Detectors</b>	
<b>SiC-Based MOSFETs for Harsh Environment Emissions Sensors</b>	
P. Sandvik, M. Ali, V. Tilak, K. Matocha, T. Stauden, J. Tucker, J. Deluca and O. Ambacher .....	1457
<b>Development of Ultra High Sensitivity UV Silicon Carbide Detectors</b>	
F. Yan, X. Xin, P. Alexandrov, C.M. Stahle, B. Guan and J.H. Zhao .....	1461
<b>Silicon Carbide Power Diodes as Radiation Detectors</b>	
B.F. Phlips, K.D. Hobart, F.J. Kub, R.E. Stahlbush, M.K. Das, G. De Geronimo and P. O'Connor .....	1465
<b>Minimum Ionizing Particle Detector Based on p<sup>+</sup>n Junction SiC Diode</b>	
F. Moscatelli, A. Scorzoni, A. Poggi, M. Bruzzi, S. Lagomarsino, S. Sciortino, G. Wagner and R. Nipoti .....	1469

## Radiation Hard Devices Based on SiC

E. Kalinina, A. Strel'chuk, A. Lebedev, N. Strokan, A. Ivanov and G. Kholuyanov ..... 1473

## The Limit of SiC Detector Energy Resolution in Ion Spectrometry

R. Yakimova, A.A. Lebedev, A.M. Ivanov, N.B. Strokan and M. Syväjärvi ..... 1477

## Chapter 7. III-Nitrides

### 7.1 Growth of III-Nitrides

#### Reduction of Defects in GaN Epitaxial Films Grown Heteroepitaxially on SiC

C.R. Eddy, Jr., N.D. Bassim, M.A. Mastro, R.L. Henry, M.E. Twigg, R.T. Holm, J.C. Culbertson, P.G. Neudeck, J.A. Powell and A.J. Trunek ..... 1483

#### Molecular Beam Epitaxy of Cubic Group III-Nitrides on Free-Standing 3C-SiC Substrates

D.J. As, S. Potthast, J Schörmann, S.F. Li, K. Lischka, H. Nagasawa and M. Abe ..... 1489

#### Surface Morphology of GaN Films Grown by RF-Plasma MBE Using Lateral Overgrowth and Low-Temperature Ga-Rich Condition

M. Shimizu, H. Chonan, G. Piao, H. Okumura and H. Nakanishi ..... 1493

#### The Effect of Aluminum Nitride-Silicon Carbide Alloy Buffer Layers on the Sublimation Growth of Aluminum Nitride on SiC (0001) Substrates

Z. Gu, J.H. Edgar, B. Raghorthamachar, M. Dudley, D. Zhuang and Z. Sitar ..... 1497

#### Growth of AlN and AlN-SiC Solid Solution by Sublimation Method

M. Anikin, D. Chaussende, E. Pernot, O. Chaix-Pluchery, H. Roussel, M. Pons and R. Madar ..... 1501

### 7.2 Physical Properties and Characterization of III-Nitrides

#### Improved Structural Quality and Carrier Decay Times in GaN Epitaxy on SiN and TiN Porous Network Templates

Ü. Özgür, C.W. Litton, Y. Fu, Y.T. Moon, F. Yun, H.O. Everitt and H. Morkoç ..... 1505

#### Electron Microscopy Investigation of the Role of Surface Steps in the Generation of Dislocations During MOCVD Growth of GaN on 4H-SiC

N.D. Bassim, M.E. Twigg, M.A. Mastro, P. Neudeck, C.R. Eddy, Jr., R.L. Henry, R.N. Holm, J.A. Powell and A.J. Trunek ..... 1509

#### Strain Relaxation in GaN/AlN Films Grown on Vicinal and On-Axis SiC Substrates

J. Bai, X. Huang, B. Raghorthamachar, M. Dudley, B. Wagner, R.F. Davis, L. Wu and Y. Zhu ..... 1513

#### Anisotropic Properties of GaN Studied by Raman Scattering

H.C. Lin, Z.C. Feng, M.S. Chen, Z.X. Shen, W. Lu and W.E. Collins ..... 1517

#### Structural Characterization of Bulk AlN Single Crystals Grown from Self-Seeding and Seeding by SiC Substrates

B. Raghorthamachar, R. Dalmau, M. Dudley, R. Schlesser, D. Zhuang, Z. Herro and Z. Sitar ..... 1521

### 7.3 III-Nitride Surfaces and Interfaces

<b>Asymmetric Interface Densities on n and p Type GaN MOS Capacitors</b>	
W. Huang, T. Khan and T.P. Chow .....	1525
<b>Effects of Rapid Thermal Annealing Treatment on the Surface Band Bending of n-type GaN Studied by Surface Potential Electric Force Microscopy</b>	
S. Chevtchenko, Q. Fan, C.W. Litton, A.A. Baski and H. Morkoç .....	1529
<b>Quantitative Mobility Spectrum Analysis of AlGaN/GaN Heterostructures Using Variable-Field Hall Measurements</b>	
N. Biyikli, C.W. Litton, J. Xie, Y.-T. Moon, F. Yun, C.-G. Stefanita, S. Bandyopadhyay, J.R. Meyer and H. Morkoç .....	1533
<b>Growth and Investigation of n-AlGaN/p-6H-SiC/n-6H-SiC Heterostructures</b>	
A.A. Lebedev, O.Yu. Ledyaev, A.M. Strel'chuk, A.N. Kuznetsov, A.E. Cherenkov, A.E. Nikolaev, A.S. Zubrilov, N.V. Seredova and A.A. Volkova .....	1537

## 7.4 III-Nitride Devices

<b>Structural Properties and Electrical Characteristics of Homoepitaxial GaN PiN Diodes</b>	
X.A. Cao, M. Larsen, H. Lu and S.D. Arthur .....	1541
<b>Electron Injection from GaN to SiC and Fabrication of GaN/SiC Heterojunction Bipolar Transistors</b>	
J. Suda, Y. Nakano, S. Shimada, K. Amari and T. Kimoto .....	1545
<b>Direct Electrical Characteristics of GaN Nanowire Field Effect Transistor (FET) without Assistance of E-Beam Lithography (EBL)</b>	
S.-K. Lee, H.-K. Seong, K.-C. Choi, N.-K. Cho, H.-J. Choi, E.-K. Suh and K.-S. Nahm .....	1549
<b>GaN Resistive Gas Sensors for Hydrogen Detection</b>	
F. Yun, T.J. Fawcett, S. Chevtchenko, Y.-T. Moon, H. Morkoç and J.T. Wolan .....	1553

## Chapter 8. Related Materials

<b>Atomic Layer Epitaxy of (Si<sub>1-x</sub>C<sub>1-y</sub>)Ge<sub>x+y</sub> Layers on 4H-SiC</b>	
J. Pezoldt, Th. Kups, P. Weih, Th. Stauden and O. Ambacher .....	1559
<b>Effect of the Crystallization Conditions on the Epitaxial Relationship of Si Deposited on 3C-SiC(100)</b>	
G. Ferro, E.K. Polychroniadis, D. Panknin, W. Skorupa, J. Stoemenos and Y. Monteil .....	1563
<b>Optical Characterization of ZnO Materials Grown by Modified Melt Growth Technique</b>	
Z.C. Feng, J.W. Yu, J.B. Wang, R. Varatharajan, B. Nemeth, J. Nause, I. Ferguson, W. Lu and W.E. Collins .....	1567
<b>The Properties of n-ZnO/p-SiC Heterojunctions and Their Potential Applications for Devices</b>	
C.W. Litton, Ya.I. Alivov, D. Johnstone, Ü. Özgür, V. Avrutin, Q. Fan, S.S. Akarca-Biyikli, K. Zhu and H. Morkoç .....	1571
<b>Role of Oxygen in Growth of Carbon Nanotubes on SiC</b>	
W. Lu, J. Boeckl, W.C. Mitchel, J. Rigueur and W.E. Collins .....	1575
<b>Structural and Electrical Characteristics of Carbon Nanotubes Formed on Silicon Carbide Substrates by Surface Decomposition</b>	
J. Boeckl, W.C. Mitchel, W. Lu and J. Rigueur .....	1579

<b>First Principles Modelling of Scroll-to-Nanotube Defect: Screw-Type Dislocation</b>	
I. Suarez-Martinez, G. Savini and M.I. Heggie .....	1583
<b>SNOM Investigation of Surface Morphology Changes during Cr/Au Contact</b>	
<b>Fabrication on Single-Crystal CVD Diamond</b>	
D. Doneedu, O.J. Guy, R.M. Baylis, L. Chen, P.R. Dunstan, P.A. Mawby, C.F. Pirri, S.	
Ferrero, D. Twitchen, A. Tajani and M. Schwitters .....	1587
<b>Author Index</b> .....	1
<b>Keyword Index</b> .....	1