

Table of Contents

Preface, Sponsors, Committees and Overview

Chapter 1: SiC Bulk Growth

1.1 PVT, CVD, Modeling and Theory

Status of Large Diameter SiC Single Crystals

A.K. Gupta, P. Wu, V. Rengarajan, X.P. Xu, M. Yoganathan, C. Martin, E. Emorhokpor, A. Souzis, I. Zwieback and T. Anderson 3

TSD Reduction by RAF (Repeated *a*-Face) Growth Method

Y. Urakami, I. Gunjishima, S. Yamaguchi, H. Kondo, F. Hirose, A. Adachi and S. Onda 9

Growth of High Quality 4H-SiC Crystals in Controlled Temperature Distributions of Seed Crystals

H. Tsuge, S. Sato, M. Katsuno, T. Fujimoto and W. Ohashi 13

Process and Crucible Modification for Growth of High Doped 4H-SiC Crystal with Larger Diameter

J.H. Park, T.K. Yang, I.S. Kim, W.J. Lee, I.G. Yeo, T.H. Eun, S.S. Lee, J.Y. Kim and M.C. Chun 17

Fundamental Study of Sublimation-Recrystallization Phenomena in PVT-Growth of SiC Single Crystals

T. Fujimoto, N. Ohtani, S. Sato, M. Katsuno, H. Tsuge and W. Ohashi 21

Analysis of Growth Velocity of SiC Growth by the Physical Vapor Transport Method

K. Kakimoto, B. Gao, T. Shiramomo, S. Nakano and S.I. Nishizawa 25

Effect of Nitrogen Doping on the Growth of 4H Polytype on the 6H-SiC Seed by PVT Method

E. Tymicki, K. Grasza, K. Racka, T. Łukasiewicz, M. Piersa, K. Kościewicz, D. Teklińska, R. Diduszko, P. Skupiński, R. Jakieła and J. Krupka 29

Lateral Growth Expansion of 4H/6H-SiC M-Plane Pseudo Fiber Crystals by Hot Wall CVD Epitaxy

A.J. Trunek, P.G. Neudeck, A.A. Woodworth, J.A. Powell, D.J. Spry, B. Raghathamachar and M. Dudley 33

Synthesis and Purification of Silicon Carbide Powders for Crystal Growth

T.C. Hsiao and S. Tsao 37

Bulk and Surface Effects on the Polytype Stability in SiC Crystals

F. Mercier and S.I. Nishizawa 41

1.2 Solution Growth

Crystallinity Evaluation of 4H-SiC Single Crystal Grown by Solution Growth Technique Using Si-Ti-C Solution

K. Kamei, K. Kusunoki, N. Yashiro, N. Okada, K. Moriguchi, H. Daikoku, M. Kado, H. Suzuki, H. Sakamoto and T. Bessho 45

SiC Growth by Solvent-Laser Heated Floating Zone

A.A. Woodworth, P.G. Neudeck, A. Sayir, D.J. Spry, A.J. Trunek and J.A. Powell 49

Stable Growth of 4H-SiC Single Polytype by Controlling the Surface Morphology Using a Temperature Gradient in Solution Growth

Y. Yamamoto, K. Seki, S. Kozawa, Alexander, S. Harada and T. Ujihara 53

Control of Void Formation in 4H-SiC Solution Growth

T. Mitani, M. Okamura, T. Takahashi, N. Komatsu, T. Kato and H. Okumura 57

Top-Seeded Solution Growth of 4H-SiC Bulk Crystal Using Si-Cr Based Melt

H. Daikoku, M. Kado, H. Sakamoto, H. Suzuki, T. Bessho, K. Kusunoki, N. Yashiro, N. Okada, K. Moriguchi and K. Kamei 61

Growth of a Thick 2H-SiC Layer in Si-Li Solution under a Continuous CH₄ Flow

M. Imade, A. Ishikawa, Y. Nakagawa, M. Yoshimura, Y. Kitaoka, T. Sasaki and Y. Mori 65

Growth Rate Prediction in SiC Solution Growth Using Silicon as Solvent

J. Lefebvre, J.M. Dedulle, T. Ouisse and D. Chaussende 69

Chapter 2: SiC Epitaxial Growth

2.1 Homoepitaxial Growth

SiC Epitaxial Layer Growth in a 6x150 mm Warm-Wall Planetary Reactor	
A.A. Burk, D. Tsvetkov, D. Barnhardt, M.J. O'Loughlin, L. Garrett, P. Towner, J. Seaman, E. Deyneca, Y. Khlebnikov and J.W. Palmour	75
Growth of 4H-SiC Epilayers and Z_{1/2} Center Elimination	
T. Miyazawa and H. Tsuchida	81
Growth and Light Properties of Fluorescent SiC for White LEDs	
M. Syväjärvi, R. Yakimova, M. Iwaya, T. Takeuchi, I. Akasaki and S. Kamiyama	87
High Uniformity with Reduced Surface Roughness of Chloride Based CVD Process on 100mm 4° Off-Axis 4H-SiC	
H. Das, S.G. Sunkari, T. Oldham, J.R.B. Casady and J.B. Casady	93
Epitaxial Growth of 4H-SiC Using Si₂(CH₃)₆+Si₂Cl₆+C₃H₈+H₂ System by Atmospheric Pressure Hot CVD Method	
H.S. Lee, M.J. Kim, M.H. Kim, S.I. Lee, W.J. Lee, B.C. Shin and S. Nishino	97
4H-SiC Epitaxial Growth on 2° Off-Axis Substrates using Trichlorosilane (TCS)	
T. Aigo, W. Ito, H. Tsuge, H. Yashiro, M. Katsuno, T. Fujimoto and W. Ohashi	101
Development of Vertical 3×2LPCVD System for Fast Epitaxial Growth on 4H-SiC	
W.S. Zhao, G.S. Sun, H.L. Wu, G.G. Yan, L. Zheng, L. Dong, L. Wang, X.F. Liu and L.J. Yang	105
Carrot Defect Control in Chloride-Based CVD through Optimized Ramp up Conditions	
M. Yazdanfar, S. Leone, H. Pedersen, O. Kordina, A. Henry and E. Janzén	109
Chloride-Based CVD of 4H-SiC at High Growth Rates on Substrates with Different Off-Angles	
S. Leone, H. Pedersen, F.C. Beyer, S. Andersson, O. Kordina, A. Henry, A. Canino, F. La Via and E. Janzén	113
Comparison of 4H Silicon Carbide Epitaxial Growths at Various Growth Pressures Using Dicholorosilane and Silane Gases	
T. Rana, H.Z. Song, M.V.S. Chandrashekhar and T.S. Sudarshan	117
In-Grown Stacking Faults in SiC-CVD Using Dichlorosilane and Propane as Precursors	
H.Z. Song, S.U. Omar, T. Rana, M.V.S. Chandrashekhar and T.S. Sudarshan	121
Investigation of Basal Plane Dislocation Reduction/Elimination by Molten KOH-NaOH Eutectic Etching Method	
H.Z. Song and T.S. Sudarshan	125
Electrical and Optical Properties of High-Purity Epilayers Grown by the Low-Temperature Chloro-Carbon Growth Method	
S.P. Kotamraju, B. Krishnan, F.C. Beyer, A. Henry, O. Kordina, E. Janzén and Y. Koshka	129
Use of Vanadium Doping for Compensated and Semi-Insulating SiC Epitaxial Layers for SiC Device Applications	
B. Krishnan, R.V.K.G. Thirumalai, S.P. Kotamraju, J.N. Merrett and Y. Koshka	133
Progress in Growth of Thick Epitaxial Layers on 4 Degree Off-Axis 4H SiC Substrates	
J. Zhang, G.Y. Chung, E. Sanchez, M.J. Loboda, S.G. Sundaresan and R. Singh	137
Improvement of Homoepitaxial Layer Quality Grown on 4H-SiC Si-Face Substrate Lower than 1 Degree Off Angle	
K. Kojima, S. Ito, A. Nagata and H. Okumura	141
Surface Morphology Evolution after Epitaxial Growth on 4°Off-Axis 4H-SiC Substrate	
N. Jegenyes, V. Soulière, F. Cauwet and G. Ferro	145
Study of the Impact of Growth and Post-Growth Processes on the Surface Morphology of 4H Silicon Carbide Films	
M. Camarda, A. Canino, P. Fiorenza, C. Bongiorno, A. Severino, V. Rainieri, A. La Magna, F. La Via, M. Mauceri, G. Abbondanza, A. Pecora and D. Crippa	149
Behavior of Particles in the Growth Reactor and their Effect on Silicon Carbide Epitaxial Growth	
T. Rana, H.Z. Song, M.V.S. Chandrashekhar and T.S. Sudarshan	153
Influence of Growth Mechanism on Carrier Lifetime in On-Axis Homoepitaxial Layers of 4H-SiC	
J. Hassan, L. Lilja, I.D. Booker, P. Bergman and E. Janzén	157

The Effect of Growth Conditions on Carrier Lifetime in N-Type 4H-SiC Epitaxial Layers L. Lilja, J. Hassan, I.D. Booker, P. Bergman and E. Janzén	161
Study of the Lateral Growth by VLS Mechanism Using Al-Based Melts on Patterned SiC Substrate J. Lorenzzi, R. Esteve, M. Lazar, D. Tournier, D. Carole and G. Ferro	165
Buried Selective Growth of p-Doped SiC by VLS Epitaxy D. Carole, S. Berckmans, A. Vo-Ha, M. Lazar, D. Tournier, P. Brosselard, V. Soulière, L. Auvray, G. Ferro and C. Brylinski	169
Reliable Method for Eliminating Stacking Fault on 3C-SiC(001) N. Hatta, T. Kawahara, K. Yagi, H. Nagasawa, S.A. Reshanov and A. Schöner	173

2.2 Heteroepitaxial and Heteropolytypic Growth

Freestanding 3C-SiC Grown by Sublimation Epitaxy Using 3C-SiC Templates on Silicon P. Hens, J. Müller, G. Wagner, R. Liljedahl, R. Yakimova, E. Specker, P.J. Wellmann and M. Syväjärvi	177
Effect of Propane on Low Temperature Growth of 3C-SiC Film on Si (111) by Plasma Assisted CVD H. Shimizu and T. Watanabe	181
Low Temperature Epitaxy of 3C SiC Using Hexamethyldisilane Precursor on Si <111> Substrates B. Wagner, J.D. Oliver, N.B. Singh, M. King, S. McLaughlin, D. Kahler, D. Knuteson, A. Berghmans and R. Rai	185
CVD Heteroepitaxial Growth of 3C-SiC on 4H-SiC (0001) Substrates X. Li, S. Leone, S. Andersson, O. Kordina, A. Henry and E. Janzén	189
On Stabilization of 3C-SiC Using Low Off-Axis 6H-SiC Substrates V. Jokubavicius, B. Lundqvist, P. Hens, R. Liljedahl, R. Yakimova, S. Kamiyama and M. Syväjärvi	193
Si_xC_y Thin Films Deposited at Low Temperature by DC Dual Magnetron Sputtering: Effect of Power Supplied to Si and C Cathode Targets on Film Physicochemical Properties H.S. Medeiros, R.S. Pessoa, J.C. Sagás, M.A. Fraga, L.V. Santos, H.S. Maciel, M. Massi and A.S. da Silva Sobrinho	197

Chapter 3: Physical Properties and Characterization of SiC

3.1 Impurities, Intrinsic Point Defects and Carrier Lifetime

Transition Metal Defects in Cubic and Hexagonal Polytypes of SiC: Site Selection, Magnetic and Optical Properties from <i>Ab Initio</i> Calculations V. Ivády, B. Somogyi, V. Zólyomi, A. Gällström, N.T. Son, E. Janzén and A. Gali	205
Electronic Configuration of Tungsten in 4H-, 6H-, and 15R-SiC A. Gällström, B. Magnusson, F.C. Beyer, A. Gali, N.T. Son, S. Leone, I.G. Ivanov, A. Henry, C.G. Hemmingsson and E. Janzén	211
Identification of Niobium in 4H-SiC by EPR and <i>Ab Initio</i> Studies N.T. Son, V. Ivády, A. Gali, A. Gällström, S. Leone, O. Kordina and E. Janzén	217
Mn Implantation for New Applications of 4H-SiC M.K. Linnarsson, J. Wong-Leung, A. Hallén, S.I. Khartsev and A.M. Grishin	221
Diffusion and Gettering of Transition Metals in 4H-SiC K. Danno, H. Saitoh, A. Seki, T. Shirai, H. Suzuki, T. Bessho, Y. Kawai and T. Kimoto	225
Chlorine in SiC: Experiment and Theory G. Alfieri and T. Kimoto	229
Photoluminescence and Raman Spectroscopy Characterization of Boron- and Nitrogen-Doped 6H Silicon Carbide Y.Y. Ou, V. Jokubavicius, C. Liu, R.W. Berg, M.K. Linnarsson, S. Kamiyama, Z.Y. Lu, R. Yakimova, M. Syväjärvi and H.Y. Ou	233
Simulation of the Temperature Dependence of Hall Carriers in Al Doped 4H-SiC A. Nath, R. Scaburri, M.V. Rao and R. Nipoti	237
Elimination of Deep Levels in Thick SiC Epilayers by Thermal Oxidation and Proposal of the Analytical Model K. Kawahara, J. Suda and T. Kimoto	241

On the Formation of Intrinsic Defects in 4H-SiC by High Temperature Annealing Steps	247
B. Zippelius, J. Suda and T. Kimoto	
Z_{1/2}- and EH₆-Center in 4H-SiC: Not Identical Defects ?	251
B. Zippelius, A. Glas, H.B. Weber, G. Pensl, T. Kimoto and M. Krieger	
Excitation Properties of Silicon Vacancy in Silicon Carbide	255
A. Gali	
Investigation of Intrinsic Carbon-Related Defects in 4H-SiC by Selective-Excitation Photoluminescence Spectroscopy	259
A. Gällström, I.G. Ivanov, R. Coble, R.P. Devaty, W.J. Choyke and E. Janzén	
Local Thermal Expansion and the C-C Stretch Vibration of the Dicarbon Antisite in 4H SiC	263
R.P. Devaty, F. Yan, W.J. Choyke, A. Gali, T. Kimoto and T. Ohshima	
Defects in an Electron-Irradiated 6H-SiC Diode Studied by Alpha Particle Induced Charge Transient Spectroscopy: Their Impact on the Degraded Charge Collection Efficiency	267
N. Iwamoto, A. Koizumi, S. Onoda, T. Makino, T. Ohshima, K. Kojima, S. Koike, K. Uchida and S. Nozaki	
Effects of Sacrifice Oxidation on Characterization of Defects in High-Purity Semi-Insulating 4H-SiC by Discharge Current Transient Spectroscopy	271
S. Nishikawa, R. Okada and H. Matsuura	
Investigation of Additional States in the Silicon Carbide Surface after Diffusion Welding	275
J. Mizsei, O. Korolkov, N. Sleptsuk, J. Toomppuu and T. Rang	
Long Carrier Lifetimes in n-Type 4H-SiC Epilayers	279
P.B. Klein	
Comparison of Post-Growth Carrier Lifetime Improvement Methods for 4H-SiC Epilayers	285
I.D. Booker, J. Hassan, A. Hallén, E.Ö. Sveinbjörnsson, O. Kordina and P. Bergman	
Radial Variation of Measured Carrier Lifetimes in Epitaxial Layers Grown with Wafer Rotation	289
P. Bergman, I.D. Booker, L. Lilja, J. Hassan and E. Janzén	
High-Resolution Time-Resolved Carrier Lifetime and Photoluminescence Mapping of 4H-SiC Epilayers	293
I.D. Booker, J. Hassan, E. Janzén and P. Bergman	
Correlation of Extended Defects on Carrier Lifetime in Thick SiC Epilayers	297
N.A. Mahadik, R.E. Stahlbush, J.D. Caldwell, M.J. O'Loughlin and A.A. Burk	
Characterization of Annealed HPSI 4H-SiC for Photoconductive Semiconductor Switches	301
C. Hettler, W.W. Sullivan III and J. Dickens	
Correlation between Strain and Excess Carrier Lifetime in a 3C-SiC Wafer	305
A. Yoshida, M. Kato and M. Ichimura	
Carrier Diffusivity in Highly Excited Bulk SiC, GaN, and Diamond Crystals by Optical Probes	309
K. Jarašūnas, P. Ščajev, T. Malinauskas, M. Kato, E. Ivakin, M. Nesladek, K. Haenen, Ü. Özgür and H. Morkoç	

3.2 Extended Defects (See also Section 3.4)

Critical Conditions of Misfit Dislocation Formation in 4H-SiC Epilayers	313
X. Zhang, T. Miyazawa and H. Tsuchida	
Fourier Transform Analysis of Basal Plane Dislocation Structure in Repeated A-Face Grown Crystals	319
I. Gunjishima, Y. Urakami, F. Hirose, A. Adachi, S. Onda and K. Nishikawa	
X-Ray Three-Dimensional Topography Imaging of Basal-Plane and Threading-Edge Dislocations in 4H-SiC	323
R. Tanuma, D. Mori, I. Kamata and H. Tsuchida	
Basal Plane Dislocation Multiplication via the Hopping Frank-Read Source Mechanism and Observations of Prismatic Glide in 4H-SiC	327
H.H. Wang, S.Y. Byrapa, F. Wu, B. Raghothamachar, M. Dudley, E. Sanchez, D.M. Hansen, R. Drachev, S.G. Mueller and M.J. Loboda	
Identification of the Basal Plane Component of the Burgers Vector of Small Dislocations in 6H SiC Using Birefringence Microscopy	331
L.T.M. Hoa, T. Ouisse, M. Seiss and D. Chaussende	

Effects of Nitrogen Doping on the Morphology of Basal Plane Dislocations in 4H-SiC Epilayers	335
X. Zhang, M. Nagano and H. Tsuchida	
Analysis of Dislocations Nucleated after Nano Indentation Tests at Room Temperature in 4H-SiC	339
J.L. Demenet, M. Amer, C. Tromas and J. Rabier	
Synchrotron X-Ray Topography Studies of the Propagation and Post-Growth Mutual Interaction of Threading Growth Dislocations with C-Component of Burgers Vector in PVT-Grown 4H-SiC	
F.Z. Wu, H.H. Wang, S.Y. Byrapa, B. Raghorthamachar, M. Dudley, E. Sanchez, D.M. Hansen, R. Drachev, S.G. Mueller and M.J. Loboda	343
Deflection of Threading Dislocations with Burgers Vector c/c+a Observed in 4H-SiC PVT-Grown Substrates with Associated Stacking Faults	
S.Y. Byrapa, F.Z. Wu, H.H. Wang, B. Raghorthamachar, G. Choi, S. Sun, M. Dudley, E. Sanchez, D.M. Hansen, R. Drachev, S.G. Mueller and M.J. Loboda	347
Conversion Mechanism of Threading Screw Dislocation during SiC Solution Growth	
T. Ujihara, S. Kozawa, K. Seki, Alexander, Y. Yamamoto and S. Harada	351
Complex Behavior of Threading Dislocations Observed in PVT-Grown 4H-SiC Single Crystals	
M. Katsuno, T. Fujimoto, H. Yashiro, H. Tsuge, S. Sato, H. Hirano, T. Yano and W. Ohashi	355
Correlation between Surface Morphological Defects and Crystallographic Defects in SiC	
T. Hatakeyama, K. Ichinoseki, H. Yamaguchi, N. Sugiyama and H. Matsuhata	359
Characterization of Triangular-Defects in 4° off 4H-SiC Epitaxial Wafers by Synchrotron X-Ray Topography and by Transmission Electron Microscopy	
T. Yamashita, K. Momose, D. Muto, Y. Shimodaira, K. Yamatake, Y. Miyasaka, T. Sato, H. Matsuhata and M. Kitabatake	363
Variation of Etch Pit Size by Screw Dislocation Tilt in 4H-SiC Wafer	
Y. Ishikawa, Y.Z. Yao, Y. Sugawara, K. Danno, H. Suzuki, Y. Kawai and N. Shibata	367
Critical Density of Nanoscale Pits for Suppressing Variability in Leakage Current of a SiC Schottky Barrier Diode	
T. Ishikawa, T. Katsuno, Y. Watanabe, H. Fujiwara and T. Endo	371
Surface Morphology of Leakage Current Sources of 4H-SiC Schottky Barrier Diodes by Atomic Force Microscope	
T. Katsuno, Y. Watanabe, T. Ishikawa, H. Fujiwara, M. Konishi, T. Morino and T. Endo	375
Density and Behavior of Etch Pits on C-Face 4H-SiC Surface Produced by ClF₃ Gas	
H. Habuka, K. Furukawa, T. Kanai and T. Kato	379
Dislocation Formation in Epitaxial Film by Propagation of Shallow Dislocations on 4H-SiC Substrate	
Y. Ishikawa, K. Sato, Y. Okamoto, N. Hayashi, Y.Z. Yao and Y. Sugawara	383
Effect of Stacking Faults Originating from Half Loop Arrays on Electrical Behavior of 10 kV 4H-SiC PiN Diodes	
R.E. Stahlbush, Q.C.J. Zhang, A.K. Agarwal and N.A. Mahadik	387
Ultraviolet Photoluminescence Imaging of Stacking Fault Contraction in 4H-SiC Epitaxial Layers	
N.A. Mahadik, R.E. Stahlbush, J.D. Caldwell and K.D. Hobart	391
Photoluminescence Study of the Driving Force for Stacking Fault Expansion in 4H-SiC	
R. Hirano, Y. Sato, M. Tajima, K.M. Itoh and K. Maeda	395
Room Temperature Photoluminescence from 4H-SiC Epilayers: Non-Destructive Estimation of In-Grown Stacking Fault Density	
S.U. Omar, H.Z. Song, T.S. Sudarshan and M.V.S. Chandrashekhar	399
Luminescence Imaging of Extended Defects in SiC via Hyperspectral Imaging	
J.D. Caldwell, L. Lombez, A. Delamarre, J.F. Guillemoles, B. Bourgoin, B.A. Hull and M. Verhaegen	403
Low Temperature Photoluminescence Signature of Stacking Faults in 6H-SiC Epilayers Grown on Low Angle Off-Axis Substrates	
J.W. Sun, T. Robert, V. Jokubavicius, S. Juillaguet, R. Yakimova, M. Syväjärvi and J. Camassel	407
Interaction of 6H-Type Stacking Faults with Threading Screw Dislocations in PVT-Grown 4H-SiC Single Crystals	
S. Sato, T. Fujimoto, H. Tsuge, M. Katsuno and W. Ohashi	411

Ab Initio Calculation of Mechanical Properties of Stacking Fault in 3C-SiC: Effect of Stress and Doping

Y. Umeno, K. Yagi and H. Nagasawa	415
On the Twin Boundary Propagation in (111) 3C-SiC Layers	
M. Marinova, A. Andreadou, A. Mantzari and E.K. Polychroniadis	419
Defect Structures at the Silicon/3C-SiC Interface	
P. Hens, J. Müller, E. Spiecker and P.J. Wellmann	423

3.3 SiC-SiO₂ Interface (See also Sections 5.1 and 6.4)

Electrically Detected Magnetic Resonance (EDMR) Studies of SiC-SiO₂ Interfaces	
T. Umeda, R. Kosugi, K. Fukuda, N. Morishita, T. Ohshima, K. Esaki and J. Isoya	427
Definitive Identification of an Important 4H SiC MOSFET Interface/Near Interface Trap	
C.J. Cochrane, P.M. Lenahan and A.J. Lelis	433
Comparative Study of Electrical and Microstructural Properties of 4H-SiC MOSFETs	
C. Strenger, V. Haeublein, T. Erlbacher, A.J. Bauer, H. Ryssel, A.M. Beltran, S. Schamm-Chardon, V. Mortet, E. Bedel-Pereira, M. Lefebvre and F. Cristiano	437
Sub-Bandgap Light-Induced Carrier Generation at Room Temperature in Silicon Carbide MOS Capacitors	
S. DasGupta, A. Armstrong, R. Kaplar, M. Marinella, R. Brock, M. Smith and S. Atcitty	441
Oxidation-Induced Epilayer Carbon Di-Interstitials as a Major Cause of Endemically Poor Mobilities in 4H-SiC/SiO₂ Structures	
X. Shen and S.T. Pantelides	445
Silicon Carbide-Silicon Dioxide Transition Layer Mobility	
S. Salemi, A. Akturk, S. Potbhare, A.J. Lelis and N. Goldsman	449
Sodium, Rubidium and Cesium in the Gate Oxides of SiC MOSFETs	
B.R. Tuttle, S. Dhar, S.H. Ryu, X. Zhu, J.R. Williams, L.C. Feldman and S.T. Pantelides	453
Total Near Interface Trap Density Calculation of 4H-SiC/SiO₂ Structures before and after Nitrogen Passivation	
S. Salemi, A. Akturk, S. Potbhare, A.J. Lelis and N. Goldsman	457
Detection of Mobile Ions in the Presence of Charge Trapping in SiC MOS Devices	
D.B. Habersat, A.J. Lelis and R. Green	461
Two-Way Tunneling Model of Oxide Trap Charging and Discharging in SiC MOSFETs	
A.J. Lelis, D.B. Habersat, R. Green and N. Goldsman	465
Peak Degradation of Heavy-Ion Induced Transient Currents in 6H-SiC MOS Capacitors	
T. Makino, N. Iwamoto, S. Onoda, T. Ohshima, K. Kojima and S. Nozaki	469
Low Frequency Noise in 4H-SiC Lateral JFET Structures	
H.K. Chan, R.C. Stevens, J.P. Goss, N.G. Wright and A.B. Horsfall	473

3.4 Stress, Structural and Mechanical Properties (See also Section 3.2)

Influence of Threading Dislocations on Lifetime of Gate Thermal Oxide	
K. Yamamoto, M. Nagaya, H. Watanabe, E. Okuno, T. Yamamoto and S. Onda	477
Doping-Induced Lattice Mismatch and Misorientation in 4H-SiC Crystals	
S. Sasaki, J. Suda and T. Kimoto	481
Strain Build-Up, Swelling and Stacking Fault Formation in Implanted 4H-SiC	
J.F. Barbot, S. Leclerc, C. Tromas, V. Audurier, A. Decléméy, M. Texier and M.F. Beaufort	485
High Resolution X-Ray Diffraction (HRXRD) Studies of the Initial Stages of PVT-Growth of 4H-SiC Crystals	
N. Ohtani, M. Katsuno, T. Fujimoto, S. Sato, H. Tsuge, W. Ohashi, H. Matsuhata and M. Kitabatake	489
On the Stability of 3C-SiC Single Crystals at High Temperatures	
D. Dompoint, I.G. Galben-Sandulache, A. Boulle, D. Chaussende, D. Eyidi, J.L. Demenet, M.F. Beaufort and J. Rabier	493
XRD Characterization for Al- and N-Doped 3C-SiC on Si (100) Substrate after Pulsed Excimer Laser Anneal	
K.Y. Lee, Y.H. Huang, C.F. Huang, C.Y. Chung, S.C. Lin and F. Zhao	497
Origin of the Warpage of 3C-SiC Wafer: Effect of Nonuniform Intrinsic Stress	
Y. Sun, S. Izumi, S. Sakai, K. Yagi and H. Nagasawa	501

Raman Scattering and X-Ray Absorption from CVD Grown 3C-SiC on Si	
Z.C. Feng, C. Chen, Q. Xu, S.P. Mendis, L.Y. Jang, C.C. Tin, K.Y. Lee, C.W. Liu, Z. Wu and Z.R. Qiu	505
4H-SiC Wafers Studied by X-Ray Absorption and Raman Scattering	
Q. Xu, H.Y. Sun, C. Chen, L.Y. Jang, E. Rusli, S.P. Mendis, C.C. Tin, Z.R. Qiu, Z. Wu, C.W. Liu and Z.C. Feng	509
Mechanical Properties of Cubic SiC, GaN and AlN Thin Films	
J. Pezoldt, R. Grieseler, T. Schupp, D.J. As and P. Schaaf	513
Extended Characterization of the Stress Fields in the Heteroepitaxial Growth of 3C-SiC on Silicon for Sensors and Device Applications	
M. Camarda, R. Anzalone, N. Piluso, A. Severino, A. Canino, F. La Via and A. La Magna	517
Stress Evaluation on Hetero-Epitaxial 3C-SiC Film on (100) Si Substrates	
R. Anzalone, M. Camarda, C. Locke, J. Carballo, N. Piluso, G. D'Arrigo, A. Severino, A.A. Volinsky, S.E. Saddow and F. La Via	521
Micro-Raman Analysis of a Micromachined 3C-SiC Cantilever	
N. Piluso, R. Anzalone, M. Camarda, A. Severino, G. D'Arrigo, A. La Magna and F. La Via	525
Single-Crystal SiC Resonators by Photoelectrochemical Etching	
M.M. Islam, C.F. Huang and F. Zhao	529
Amorphous Silicon Carbide (α-SiC) Thin Square Membranes for Resonant Micromechanical Devices	
A.C. Barnes, C.A. Zorman and P.X.L. Feng	533
Amorphous Silicon Carbide as a Non-Biofouling Structural Material for Biomedical Microdevices	
C.A. Zorman, A. Eldridge, J.G. Du, M. Johnston, A. Dubnisheva, S. Manley, W. Fissell, A. Fleischman and S. Roy	537

3.5 Fundamental Properties, Nanostructures, Surfaces and Miscellaneous Characterization

Seebeck Coefficient of Heavily Doped Polycrystalline 3C-SiC Deposited by LPCVD	
M.I. Lei and M. Mehregany	541
OBIC Measurements on Avalanche Diodes in 4H-SiC for the Determination of Impact Ionization Coefficients	
D.M. Nguyen, C. Raynaud, M. Lazar, G. Pâques, S. Scharnholz, N. Dheilly, D. Tournier and D. Planson	545
Radiation Hardness of Wide-Bandgap Materials as Exemplified by SiC Nuclear Radiation Detectors	
A.M. Ivanov, A.V. Sadokhin, N.B. Strokan, A.A. Lebedev and V.V. Kozlovski	549
Terahertz Electroluminescence of 6H-SiC Natural SiC Superlattice in Bloch Oscillations Regime	
V.I. Sankin, A.V. Andrianov, A.G. Petrov, P.P. Shkreby and A.O. Zachar'in	553
Emission Enhancement of SiC/SiO₂ Core/Shell Nanowires Induced by the Oxide Shell	
F. Fabbri, F. Rossi, G. Attolini, M. Bosi, G. Salviati, S. Iannotta, L. Aversa, R. Verucchi, M. Nardi, N. Fukata, B. Dierre and T. Sekiguchi	557
Theoretical Study of Thermoelectric Properties of SiC Nanowires	
J.H. Choi, M. Pala, L. Latu-Romain and E. Bano	561
GaAs Nanowires: A New Place to Explore Polytype Physics	
T. Cheiwchanchamnangij, T. Birkel, W.R.L. Lambrecht and A.L. Efros	565
The Atomic Step Induced by off Angle CMP Influences the Electrical Properties of the SiC Surface	
Y. Tanaka, T. Kanda, K. Nagatoshi, M. Yoshimura and O. Eryu	569
Surface Phase Diagram of 4H-SiC {0001} Step-Terrace Structures during Si-Vapor Etching in a TaC Crucible	
S. Ushio, T. Karaki, K. Hagiwara, N. Ohtani and T. Kaneko	573
Morphological Instability of 4H-SiC (0001) Basal Plane Surface during Si-Vapor Thermal Etching	
S. Ushio, K. Nakanishi, N. Ohtani and T. Kaneko	577
First-Principles Analysis of Dissociative Absorption of HF Molecule at SiC Surface Step Edge	
K. Inagaki, B.V. Pho, K. Yamauchi and Y. Morikawa	581

Characterization of Photoelectrochemical Properties of SiC as a Water Splitting Material	585
T. Yasuda, M. Kato and M. Ichimura	
Room Temperature Physical Characterization of Implanted 4H- and 6H-SiC	
K. Zekentes, K. Tsagaraki, M. Androulidaki, M. Kayambaki, A. Stavriniidis, H. Peyre and J. Camassel	589

Chapter 4: Graphene

4.1 Graphene Growth, Characterization and Theory

Electronic and Structural Properties of Turbostratic Epitaxial Graphene on the 6H-SiC (000-1) Surface	
T. Jayasekera, K.W. Kim and M.B. Nardelli	595
Spatially Graded Graphitization on 4H-SiC (0001) with Si-Sublimation Gradient for High Quality Epitaxial Graphene Growth	
S. Ushio, Y. Kutsuma, A. Yoshii, N. Tamai, N. Ohtani and T. Kaneko	601
Control of Epitaxial Graphene Thickness on 4H-SiC(0001) and Buffer Layer Removal through Hydrogen Intercalation	
J. Hassan, C. Virojanadara, A. Meyer, I.G. Ivanov, J.I. Flege, S. Watcharinyanon, J. Falta, L.I. Johansson and E. Janzén	605
Graphene on Carbon-Face SiC{0001} Surfaces Formed in a Disilane Environment	
N. Srivastava, G.W. He and R.M. Feenstra	609
The Registry of Graphene Layers Grown on SiC(000-1).	
L.I. Johansson, S. Watcharinyanon, A.A. Zakharov, R. Yakimova and C. Virojanadara	613
Large Area Quasi-Free Standing Monolayer Graphene on 3C-SiC(111)	
U. Starke, C. Coletti, K. Emtsev, A.A. Zakharov, T. Ouisse and D. Chaussende	617
CVD Growth of Graphene on 2" 3C-SiC/Si Templates: Influence of Substrate Orientation and Wafer Homogeneity	
M. Portail, A. Michon, S. Vézian, D. Lefebvre, S. Chenot, A. Ouerghi, M. Zielinski, T. Chassagne and Y. Cordier	621
Structural and Electrical Properties of Graphene Films Grown by Propane/Hydrogen CVD on 6H-SiC(0001)	
A. Michon, E. Roudon, M. Portail, B. Jouault, S. Contreras, S. Chenot, Y. Cordier, D. Lefebvre, S. Vézian, M. Zielinski, T. Chassagne and J. Camassel	625
Local Solid Phase Epitaxy of Few-Layer Graphene on Silicon Carbide	
E. Escobedo-Cousin, K. Vassilevski, I.P. Nikitina, N.G. Wright, A.G. O'Neill, A.B. Horsfall and J.P. Goss	629
Study of Epitaxial Graphene on Non-Polar 6H-SiC Faces	
B.K. Daas, K.M. Daniels, S. Shetu, T.S. Sudarshan and M.V.S. Chandrashekhar	633
Micro- and Nano-Scale Electrical Characterization of Epitaxial Graphene on Off-Axis 4H-SiC (0001)	
F. Giannazzo, C. Bongiorno, S. Di Franco, E. Rimini and V. Raineri	637
Electrical Characterization of the Graphene-SiC Heterojunction	
T.J. Anderson, K.D. Hobart, L.O. Nyakiti, V.D. Wheeler, R.L. Myers-Ward, J.D. Caldwell, F.J. Bezares, D.K. Gaskill, C.R. Eddy, F.J. Kub, G.G. Jernigan, M.J. Tadjer and E.A. Imhoff	641
Epitaxial Single-Layer Graphene on the SiC Substrate	
S.Y. Davydov and A.A. Lebedev	645

4.2 Graphene Processing

Decoupling the Graphene Buffer Layer from SiC(0001) via Interface Oxidation	
M. Ostler, R.J. Koch, F. Speck, F. Fromm, H. Vita, M. Hundhausen, K. Horn and T. Seyller	649
Studies of Li Intercalation into Epitaxial Graphene on SiC(0001)	
C. Virojanadara, S. Watcharinyanon, A.A. Zakharov, R. Yakimova and L.I. Johansson	653
Plasma-Based Chemical Modification of Epitaxial Graphene	
S.G. Walton, S.C. Hernández, M. Baraket, V.D. Wheeler, L.O. Nyakiti, R.L. Myers-Ward, C.R. Eddy and D.K. Gaskill	657
Evidence of Electrochemical Graphene Functionalization by Raman Spectroscopy	
K.M. Daniels, B.K. Daas, N. Srivastava, C. Williams, R.M. Feenstra, T.S. Sudarshan and M.V.S. Chandrashekhar	661

Molecular Gas Adsorption Induced Carrier Transport Studies of Epitaxial Graphene Using IR Reflection Spectroscopy

B.K. Daas, W.K. Nomani, K.M. Daniels, T.S. Sudarshan, G. Koley and M.V.S. Chandrashekhar

665

4.3 Graphene Devices and Sensors

High Performance RF FETs Using High-k Dielectrics on Wafer-Scale Quasi-Free-Standing Epitaxial Graphene

J.A. Robinson, M.J. Hollander, M. LaBella, K. Trumbull, M. Zhu, R. Cavalero and D. Snyder

669

Gated Epitaxial Graphene Devices

D. Waldmann, J. Jobst, F. Speck, T. Seyller, M. Krieger and H.B. Weber

675

Suppression of Hole Current in Graphene Transistors with N-Type Doped SiC Source/Drain Regions

Y. Nagahisa and E. Tokumitsu

679

T- and Y-Branched Three-Terminal Junction Graphene Devices

J. Pezoldt, R. Göckeritz, B. Hähnlein, B. Händel and F. Schwierz

683

Development of FETs and Resistive Devices Based on Epitaxially Grown Single Layer Graphene on SiC for Highly Sensitive Gas Detection

R. Pearce, R. Yakimova, L. Hultman, J. Eriksson, M. Andersson and A. Lloyd Spetz

687

Temperature Dependent Chemical Sensitivity of Epitaxial Graphene

V.K. Nagareddy, D.K. Gaskill, J.L. Tedesco, R.L. Myers-Ward, C.R. Eddy, J.P. Goss, N.G. Wright and A.B. Horsfall

691

Chapter 5: Processing of SiC

5.1 MOS Processing, SiC-SiO₂ Interface and Other Dielectrics (See also Sections 3.3 and 6.4)

Synchrotron Radiation Photoelectron Spectroscopy Study of Thermally Grown Oxides on 4H-SiC(0001) Si-Face and (000-1) C-Face Substrates

H. Watanabe, T. Hosoi, T. Kirino, Y. Uenishi, A. Chanthaphan, A. Yoshigoe, Y. Teraoka, S. Mitani, Y. Nakano, T. Nakamura and T. Shimura

697

Challenges of High-Performance and High-Reliability in SiC MOS Structures

J. Senzaki, A. Shimozato, K. Kojima, T. Kato, Y. Tanaka, K. Fukuda and H. Okumura

703

Effect of Post-Oxidation Annealing in Wet O₂ and N₂O Ambient on Thermally Grown SiO₂/4H-SiC Interface for P-Channel MOS Devices

S. Katakami, M. Arai, K. Takenaka, Y. Yonezawa, H. Ishimori, M. Okamoto, K. Kojima and K. Fukuda

709

Temperature Dependence of Inversion Layer Carrier Concentration and Hall Mobility in 4H-SiC MOSFETs

S. Dhar, A.C. Ahyi, J.R. Williams, S.H. Ryu and A.K. Agarwal

713

Effects of N Incorporation on Electron Traps at SiO₂/SiC Interfaces

A.F. Basile, S. Dhar, J.R. Williams, L.C. Feldman and P.M. Mooney

717

Impact of Interface Defect Passivation on Conduction Band Offset at SiO₂/4H-SiC Interface

T. Hosoi, T. Kirino, A. Chanthaphan, Y. Uenishi, D. Ikeguchi, A. Yoshigoe, Y. Teraoka, S. Mitani, Y. Nakano, T. Nakamura, T. Shimura and H. Watanabe

721

Effect of Direct Nitridation of 4H-SiC Surface on MOS Interface States

T. Sakai, M. Hemmi, Y. Murata, T. Yamakami, R. Hayashibe, Y. Onuma and K. Kamimura

725

Improved Deposited Oxide Interfaces from N₂ Conditioning of Bare SiC Surfaces

J. Rozen, M. Nagano and H. Tsuchida

729

Development of 4H-SiC MOSFETs with Phosphorus-Doped Gate Oxide

D. Okamoto, H. Yano, T. Hatayama and T. Fuyuki

733

Effect of POCl₃ Annealing on Reliability of Thermal Oxides Grown on 4H-SiC

R. Morishita, H. Yano, D. Okamoto, T. Hatayama and T. Fuyuki

739

The Effects of Phosphorus at the SiO₂/4H-SiC Interface

Y.K. Sharma, A.C. Ahyi, T. Issacs-Smith, X. Shen, S.T. Pantelides, X.G. Zhu, J. Rozen, L.C. Feldman, J.R. Williams, Y. Xu and E. Garfunkel

743

SiO₂/SiC Interfacial Region: Presence of Silicon Oxycarbides and Effects of Hydrogen Peroxide and Water Vapor Thermal Treatments

F.C. Stedile, C. Radtke, G.V. Soares, E. Pitthan, R. Palmieri and S.A. Corrêa

747

Improvement in the SiO₂/4H-SiC Interfacial Region by Thermal Treatments with Hydrogen Peroxide		
E. Pitthan, S.A. Corrêa, R. Palmieri, G.V. Soares, H.I. Boudinov and F.C. Stedile	753	
Electron Trapping in 4H-SiC MOS Capacitors Fabricated by Sodium-Enhanced Oxidation		
A.F. Basile, A.C. Ahyi, L.C. Feldman, J.R. Williams and P.M. Mooney	757	
Passivation and Depassivation of Interface Traps at the SiO₂/4H-SiC Interface by Potassium Ions		
P.G. Hermannsson and E.Ö. Sveinbjörnsson	761	
Impact of UV Irradiation on Thermally Grown 4H-SiC MOS Devices		
D. Ikeguchi, T. Kirino, S. Mitani, Y. Nakano, T. Nakamura, T. Hosoi, T. Shimura and H. Watanabe	765	
Study of High Temperature Microwave Annealing on the Performance of 4H-SiC MOS Capacitors		
H. Naik, Z. Li, H. Issa, Y.L. Tian and T.P. Chow	769	
Comparison of Oxide Quality for Monolithically Fabricated SiC CMOS Structures		
L.C. Martin, D.T. Clark, E.P. Ramsay, A.E. Murphy, R.F. Thompson, D.A. Smith, R.A.R. Young, J.D. Cormack, N.G. Wright and A.B. Horsfall	773	
A Reduction of Defects in the SiO₂-SiC System Using the SiC Vacuum Field-Effect Transistor (VacFET)		
K.M. Speer, P.G. Neudeck and M. Mehregany	777	
Controlling Characteristics of 4H-SiC(0001) p-Channel MOSFETs Fabricated on Ion-Implanted n-Well		
M. Okamoto, M. Iijima, T. Nagano, K. Fukuda and H. Okumura	781	
Two-Dimensional Roughness Growth at Surface and Interface of SiO₂ Films during Thermal Oxidation of 4H-SiC(0001)		
R. Hasunuma, T. Fukasawa, R. Kosugi, Y. Ishida and K. Yamabe	785	
Effects of Surface Morphological Defects and Crystallographic Defects on Reliability of Thermal Oxides on C-Face		
T. Suzuki, H. Yamaguchi, T. Hatakeyama, H. Matsuhata, J. Senzaki, K. Fukuda, T. Shinohe and H. Okumura	789	
Frequency-Dependent Charge Pumping on 4H-SiC MOSFETs		
L.C. Yu, J. Fronheiser, V. Tilak and K.P. Cheung	793	
Implementation of Sub-Resolvable Features for Precise Electrical Characterization of SiC Gate Oxide Parameters		
J.J. McMahon, L.C. Yu, J. Fronheiser, J.T. Elson, R. Kovalec, J. Kretchmer and V. Tilak	797	
Identification of Slow States at the SiO₂/SiC Interface through Sub-Bandgap Illumination		
C.M. Spargo, B.J.D. Furnival, R.M. Mahapatra, J.P. Goss, N.G. Wright and A.B. Horsfall	801	
Effect of Nuclear Scattering Damage at SiO₂/SiC and Al₂O₃/SiC Interfaces – a Radiation Hardness Study of Dielectrics		
M. Usman, A. Hallén, K. Gulbinas and V. Grivickas	805	
High Temperature Reliability of High-k/SiC MIS Hydrogen Sensors		
B.J.D. Furnival, N.G. Wright and A.B. Horsfall	809	
5.2 Doping, Ion Implantation and Contacts		
Shallow Incorporation of Nitrogen in HPSI 4H-SiC through the Laser Enhanced Diffusion Process		
W.W. Sullivan III, C. Hettler and J. Dickens	813	
High Dose Al⁺ Implanted and Microwave Annealed 4H-SiC		
R. Nipoti, A. Nath, M.V. Rao, A. Hallén, F. Mancarella, S. Zampolli and Y.L. Tian	817	
High Temperature Ion Implantation and Activation Annealing Technologies for Mass Production of SiC Power Devices		
K. Tezuka, T. Tsuyuki, S. Shimizu, S. Nakamata, T. Tsuji, N. Iwamuro, S. Harada, K. Fukuda and H. Kimura	821	
Effects of Different Post-Implantation Annealing Conditions on the Electrical Properties of Interfaces to p-Type Implanted 4H-SiC		
A. Frazzetto, F. Roccaforte, F. Giannazzo, R. Lo Nigro, M. Saggio, E. Zanetti and V. Raineri	825	
The Thickness-Ratio Effects of Ni/Nb Electrode on Wire Bonding Strength with N-Type 4H-SiC		
K. Jung, D. Ando, Y. Sutou, T. Oyamada, M. Tanaka and J. Koike	829	

The Formation Mechanism of Ni-Based Ohmic Contacts to 4H-n-SiC	
A.V. Kuchuk, K. Gołaszewska, V.P. Kladko, M. Guziewicz, M. Wzorek, E. Kamińska and A. Piotrowska	833
Electroless Nickel for N-Type Contact on 4H-SiC	
S.P. Mendis, C.C. Tin, M.T. Tin, T. Isaacs-Smith and E.R. Crandall	837
Development of an Extreme High Temperature n-Type Ohmic Contact to Silicon Carbide	
L.J. Evans, R.S. Okojie and D. Lukco	841
Investigation of Ti_3SiC_2 MAX Phase Formation onto N-Type 4H-SiC	
A. Drevin-Bazin, J.F. Barbot, T. Cabioc'h and M.F. Beaufort	845
GaZnO as a Transparent Electrode to Silicon Carbide	
J.H. Lee, J.H. Kim, K.M. Do, B.M. Moon, S.J. Joo, W. Bahng, S.C. Kim, N.K. Kim and S.M. Koo	849
Common Metal Die Attachment for SiC Power Devices Operated in an Extended Junction Temperature Range	
S. Tanimoto, K. Matsui, Y. Zushi, S. Sato, Y. Murakami, M. Takamori and T. Iseki	853
Metal Work-function and Doping-Concentration Dependent Barrier Height of Ni-Contacts to 4H-SiC with Metal-Embedded Nano-Particles	
M.S. Kang, J.H. Lee, A. Hallén, C. Zetterling, W. Bahng, N.K. Kim and S.M. Koo	857
5.3 Cutting, Etching, Micro- and Nano-Processing	
Cutting Speed of Electric Discharge Machining for SiC Ingot	
H. Yamada, S. Yamaguchi, N. Yamamoto and T. Kato	861
Cutting of SiC Wafer by Atmospheric-Pressure Plasma Etching with Wire Electrode	
Y. Sano, K. Aida, T. Kato, K. Yamamura, H. Mimura, S. Matsuyama and K. Yamauchi	865
Curious Relationship between Orientation of SiC Substrates and Chemical Reactivity	
T. Hatayama, H. Koketsu, H. Yano and T. Fuyuki	869
High-Resolution TEM Observation of 4H-SiC (0001) Surface Planarized by Catalyst-Referred Etching	
B.V. Pho, S. Sadakuni, T. Okamoto, R. Sagawa, K. Arima, Y. Sano and K. Yamauchi	873
Novel Cleaning Method of SiC Wafer with Transition Metal Complex	
M. Kubo, M. Hidaka, M. Kageyama, T. Okano and H. Kobayashi	877
Clearance of 4H-SiC Sub-Trench in Hot Chlorine Treatment	
H. Koketsu, T. Hatayama, H. Yano and T. Fuyuki	881
SIMS Analyses Applied to Open an Optical Window in 4H-SiC Devices for Electro-Optical Measurements	
M. Lazar, F. Jomard, D.M. Nguyen, C. Raynaud, G. Pâques, S. Scharnholz, D. Tournier and D. Planson	885
Focused Ion-Beam (FIB) Nanomachining of Silicon Carbide (SiC) Stencil Masks for Nanoscale Patterning	
H. Zamani, S.W. Lee, A. Avishai, C.A. Zorman, R.M. Sankaran and P.X.L. Feng	889
Hexagonal Faceted SiC Nanopillars Fabricated by Inductively Coupled SF_6/O_2 Plasma Method	
J.H. Choi, L. Latu-Romain, T. Baron, T. Chevolleau and E. Bano	893
Epitaxial Growth, Mechanical, Electrical Properties of SiC/Si and SiC/Poli-Si	
M. Bosi, G. Attolini, B.E. Watts, A. Roncaglia, A. Poggi, F. Mancarella, F. Moscatelli, L. Belsito and F. Matteo	897
ECR-Etching of Submicron and Nanometer Sized 3C-SiC(100) Mesa Structures	
L. Hiller, T. Stauden, R.M. Kemper, J.K.N. Lindner, D.J. As and J. Pezoldt	901
Local Anodic Oxidation of Phosphorous-Implanted 4H-SiC by Atomic Force Microscopy	
J.H. Lee, J.J. Ahn, A. Hallén, C. Zetterling and S.M. Koo	905

Chapter 6: SiC Devices, Circuits and Systems

6.1 Schottky Barrier Diodes

Impact of Surface Morphology above Threading Dislocations on Leakage Current in 4H-SiC Diodes	
F. Hirokazu, T. Katsuno, T. Ishikawa, H. Naruoka, M. Konishi, T. Endo, Y. Watanabe, K. Tsuruta, S. Onda, A. Adachi, M. Nagao and K. Hamada	911
Experimental Demonstration of 1200V SiC-SBDs with Lower Forward Voltage Drop at High Temperature	
T. Tsuji, A. Kinoshita, N. Iwamuro, K. Fukuda, K. Tezuka, T. Tsuyuki and H. Kimura	917
Performance of a 650V SiC Diode with Reduced Chip Thickness	
R. Rupp, R. Gerlach, U. Kirchner, A. Schlögl and R. Kern	921
A Fully Electrically Isolated Package for High Temperature SiC Sensors	
G. Brezeanu, F. Draghici, M. Badila, I. Rusu, F. Bernea and P. Godignon	925
Current Distribution in the Various Functional Areas of a 600V SiC MPS Diode in Forward Operation	
R. Rupp, R. Gerlach and A. Kabakow	929
4H-SiC Trench Structure Schottky Diodes	
M. Aketa, Y. Yokotsuji, M. Miura and T. Nakamura	933
Influence of Anode Layout on the Performance of SiC JBS Diodes	
R. Radhakrishnan and J.H. Zhao	937
Performance of Hybrid 4.5 kV SiC JBS Freewheeling Diode and Si IGBT	
K.D. Hobart, E.A. Imhoff, F.J. Kub, A.R. Hefner, T.H. Duong, J.M. Ortiz-Rodriguez, S.H. Ryu, D. Grider, S. Leslie, J. Sherbondy and B. Ray	941
Hybrid Si-IGBT/SiC Rectifier Co-Packs and SiC JBS Rectifiers Offering Superior Surge Current Capability and Reduced Power Losses	
S.G. Sundaresan, C. Sturdevant, H. Issa, M. Marripelly, E. Lieser and R. Singh	945

6.2 PiN and Heterojunction Diodes

12.9 kV SiC PiN Diodes with Low On-State Drops and High Carrier Lifetimes	
S.G. Sundaresan, C. Sturdevant, M. Marripelly, E. Lieser and R. Singh	949
Design, Yield and Process Capability Study of 8 kV 4H-SiC PIN Diodes	
A. Bolotnikov, P.A. Losee, K. Matocha, J. Nasadoski, J. Glaser, S. Arthur, Z. Stum, J. Garrett, A. Elasser, L. Stevanovic, H. Naik and T.P. Chow	953
Characterization of Packaged 6.5 kV SiC PiN-Diodes up to 300 °C	
K.O. Dohnke, D. Peters and R. Schörner	957
11.72 cm² SiC Wafer-Scale Interconnected 1.8 kV / 64 kA PiN Diode	
M. Snook, H. Hearne, T. McNutt, V. Veliadis, B. Nechay, S. Woodruff, R.S. Howell, D. Giorgi, J. White and S. Davis	961
Transient Electrical Characteristics of Electron Irradiated High Blocking Voltage 4H-SiC Pin Diode	
K. Asano, A. Tanaka, S. Ogata, K. Nakayama and Y. Miyanagi	965
600 V PIN Diodes Fabricated Using On-Axis 4H Silicon Carbide	
G. Civrac, F. Laariedh, N. Thierry-Jebali, M. Lazar, D. Planson, P. Brosselard, J. Hassan, A. Henry, E. Janzén, B. Vergne and S. Scharnholz	969
Experimental Study on Various Junction Termination Structures Applied to 15 kV 4H-SiC PiN Diodes	
H. Niwa, G. Feng, J. Suda and T. Kimoto	973
Single Photolithography/Implantation 120-Zone Junction Termination Extension for High-Voltage SiC Devices	
M. Snook, T. McNutt, C. Kirby, H. Hearne, V. Veliadis, B. Nechay, S. Woodruff, R.S. Howell, J. White and S. Davis	977
Positive Temperature Coefficient SiC PiN Diodes	
E.A. Imhoff, K.D. Hobart, F.J. Kub, M.G. Ancona, R.L. Myers-Ward, N.Y. Garces, V.D. Wheeler, L.O. Nyakiti, C.R. Eddy and D.K. Gaskill	981
Fully Ion Implanted Vertical p-i-n Diodes on High Purity Semi-Insulating 4H-SiC Wafers	
R. Nipoti, A. Nath, Y.L. Tian, F. Tamarri, F. Moscatelli, P. de Nicola and M.V. Rao	985
Electrical Characteristics of 4H-SiC Pin Diode with Carbon Implantation or Thermal Oxidation	
K. Nakayama, A. Tanaka, K. Asano, T. Miyazawa, M. Ito and H. Tsuchida	989

Physical Modelling of 4H-SiC PiN Diodes		
C.A. Fisher, M.R. Jennings, A.T. Bryant, A. Pérez-Tomás, P.M. Gammon, P. Brosselard, P. Godignon and P.A. Mawby	993	
Thermal Stress Response of Silicon Carbide pin Diodes Used as Photovoltaic Devices		
S. Barker, K.V. Vassilevski, I.P. Nikitina, N.G. Wright and A.B. Horsfall	997	
Effect of Surface Morphology on the On-State Resistance of SiC Photoconductive Semiconductor Switches		
X.C. Liu, W. Huang, S.H. Chang, M.X. Zhu, J.H. Yang and E.W. Shi	1001	
Novel Low V_{ON} Poly-Si/4H-SiC Heterojunction Diode Using Energy Barrier Height Control		
S. Yamagami, T. Hayashi and M. Hoshi	1005	
Fabrication of 4H-SiC/Nanocrystalline Diamond PN Junctions		
R. Amano, M. Goto, Y. Kato and K. Teii	1009	

6.3 JFETs and SITs

Recovery of Bipolar-Current Induced Degradations in High-Voltage Implanted-Gate Junction Field Effect Transistors		
V. Veliadis, H. Hearne, W. Chang, J.D. Caldwell, E.J. Stewart, M. Snook, R.S. Howell, D. Urciuoli, A.J. Lelis and C. Scozzie	1013	
Demonstration of SiC Vertical Trench JFET Reliability		
K.M. Speer, K. Chatty, V. Bondarenko, D.C. Sheridan, K. Matocha and J.B. Casady	1017	
Reliable Operation of 1200-V SiC Vertical Junction-Field-Effect-Transistor Subjected to 16,000-Pulse Hard Switching Stressing		
K. Lawson, G. Alvarez, S.B. Bayne, V. Veliadis, H.C. Ha, D. Urciuoli and C. Scozzie	1021	
Avalanche Breakdown Energy in Silicon Carbide Junction Field Effect Transistors		
M. Hinojosa, S. Bayne, V. Veliadis and D. Urciuoli	1025	
Characterization of SiC JFET in Novel Packaging for 1 MHz Operation		
K. Okamura, K. Ise, M. Wake, Y. Osawa, K. Takaki and K. Takayama	1029	
Packaging Technologies for 500°C SiC Electronics and Sensors		
L.Y. Chen, R.W. Johnson, P.G. Neudeck, G.M. Beheim, D.J. Spry, R.D. Meredith and G.W. Hunter	1033	
High Voltage SiC Vertical JFET for High Power RF Applications		
C. Hecht, R. Elpelt, R. Schörner, R. Irsigler and O. Heid	1037	
Design of an Integrated SiC JFET Power Switch and Flyback Diode		
R. Radhakrishnan and J.H. Zhao	1041	
A Novel 4H-SiC Fault Isolation Device with Improved Trade-Off between On-State Voltage Drop and Short Circuit SOA		
W.J. Sung, B.J. Baliga and A.Q. Huang	1045	
Fabrication Issues of 4H-SiC Static Induction Transistors		
A. Stavrinidis, G. Konstantinidis, M. Kayambaki, F. Cayrel, D. Alquier, Z. Gao and K. Zekentes	1049	

6.4 MOSFETs (See also Sections 3.3 and 5.1)

High Performance SiC IEMOSFET/SBD Module		
S. Harada, Y. Hoshi, Y. Harada, T. Tsuji, A. Kinoshita, M. Okamoto, Y. Makifuchi, Y. Kawada, K. Imamura, M. Gotoh, T. Tawara, S. Nakamata, T. Sakai, F. Imai, N. Ohse, M. Ryo, A. Tanaka, K. Tezuka, T. Tsuyuki, S. Shimizu, N. Iwamuro, Y. Sakai, H. Kimura, K. Fukuda and H. Okumura	1053	
Development of 1200 V, 3.7 mΩ-cm² 4H-SiC DMOSFETs for Advanced Power Applications		
S.H. Ryu, L. Cheng, S. Dhar, C. Capell, C. Jonas, R. Callanan, M.J. O'Loughlin, A.A. Burk, A.J. Lelis, C.J. Scozzie, A.K. Agarwal and J.W. Palmour	1059	
High-Temperature Performance of 1200 V, 200 A 4H-SiC Power DMOSFETs		
L. Cheng, S.H. Ryu, A.K. Agarwal, M.J. O'Loughlin, A.A. Burk, J. Richmond, A.J. Lelis, C. Scozzie and J.W. Palmour	1065	
690V, 1.00 mΩcm² 4H-SiC Double-Trench MOSFETs		
Y. Nakano, R. Nakamura, H. Sakairi, S. Mitani and T. Nakamura	1069	
SiC MOSFET Reliability Update		
M.K. Das, S.K. Haney, J. Richmond, A. Olmedo, Q.J. Zhang and Z. Ring	1073	
Material Defects and Rugged Electrical Power Switching in Semiconductors		
K. Shenai, P.G. Neudeck, M. Dudley and R.F. Davis	1077	

Comparative Study of SiC MOSFETs in High Voltage Switching Operation	1081
T. Funaki, Y. Nakano and T. Nakamura	
Charge Trapping in Sic Power MOSFETs and its Consequences for Robust Reliability Testing	1085
R. Green, A.J. Lelis and D.B. Habersat	
4H-SiC MOSFETs with a Stable Protective Coating for Harsh Environment Applications	1089
W. Daves, A. Krauss, V. Häublein, A.J. Bauer and L. Frey	
Integration of Temperature and Current Sensors in 4H-SiC VDMOS	1093
M. Berthou, P. Godignon, P. Brosselard, D. Tournier and J. Millán	
SiC-MOSFET Structure Enabling Fast Turn-On and -Off Switching	1097
S. Hino, N. Miura, A. Furukawa, S. Watanabe, Y. Nakao, S. Nakata, M. Imaizumi, H. Sumitani and T. Oomori	
Calibration of Mobility and Interface Trap Parameters for High Temperature TCAD Simulation of 4H-SiC VDMOSFETs	1101
M.G. Jaikumar and S. Karmalkar	
4H-SiC MOSFETs with Si-Like Low-Frequency Noise Characteristics	1105
S.L. Rumyantsev, M.S. Shur, M.E. Levinshtein, P.A. Ivanov, J.W. Palmour, A.K. Agarwal and S. Dhar	
High Temperature Performance of 3C-SiC MOSFETs with High Channel Mobility	1109
H. Uchida, A. Minami, T. Sakata, H. Nagasawa and M. Kobayashi	
Dependence of the Channel Mobility in 3C-SiC n-MOSFETs on the Crystal Orientation and Channel Length	1113
B. Zippelius, M. Hauck, S. Beljakowa, H.B. Weber, M. Krieger, H. Nagasawa, H. Uchida, G. Pensl and A. Schöner	

6.5 Bipolar Transistors

Enhanced Current Gain (>250) in 4H-SiC Bipolar Junction Transistors by a Deep-Level-Reduction Process	1117
H. Miyake, T. Kimoto and J. Suda	
100 and $\rho_{ON}3 \text{ m}\Omega\text{cm}^2$	1123
M. Domeij, A. Konstantinov, A. Lindgren, C. Zaring, K. Gumaelius and M. Reimark	
1200 V-Class 4H-SiC “Super” Junction Transistors with Current Gains of 88 and Ultra-Fast Switching Capability	1127
R. Singh, S. Jeliazkov and E. Lieser	
Investigation of Current Gain Degradation in 4H-SiC Power BJTs	1131
B. Buono, R. Ghandi, M. Domeij, B.G. Malm, C. Zetterling and M. Östling	
Development of 15 kV 4H-SiC IGBTs	1135
S.H. Ryu, L. Cheng, S. Dhar, C. Capell, C. Jonas, J. Clayton, M. Donofrio, M.J. O'Loughlin, A.A. Burk, A.K. Agarwal and J.W. Palmour	
Ultra high performance of 12kV Clustered Insulated Gate Bipolar Transistor (CIGBT) in 4H-SiC	1139
K.G. Menon, L.K. Ngwendson, A. Nakajima, E.M. Sankara Narayanan and G.P. Bruce	
An Investigation of Material Limit Characteristics of SiC IGBTs	1143
T. Hatakeyama, K. Fukuda and H. Okumura	
Improved Energy Efficiency Using an IGBT/SiC-Schottky Diode Pair	1147
N.A. Parker-Allotey, D.P. Hamilton, O. Alatise, M.R. Jennings, P.A. Mawby, R. Nash and R. Magill	

6.6 Thyristors and GTOs

12 kV, 1 cm² SiC GTO Thyristors with Negative Bevel Termination	1151
Q.J. Zhang, A.K. Agarwal, C. Capell, L. Cheng, M.J. O'Loughlin, A.A. Burk, J.W. Palmour, S.L. Rumyantsev, T. Saxena, M.E. Levinshtein, A. Ogunniyi, H. O'Brien and C. Scozzie	
High dI/dt Pulse Switching of 1.0 cm² SiC GTOs	1155
H. O'Brien, W. Shaheen, A. Ogunniyi, C. Scozzie, Q.J. Zhang, A.K. Agarwal and V. Temple	
Integrated SiC Anode Switched Thyristor Modules for Smart-Grid Applications	1159
S.G. Sundaresan, E. Lieser and R. Singh	
Fabrication and Characterization of 4H-SiC 6kV Gate Turn-Off Thyristor	1163
L. Lin and J.H. Zhao	

Comparison of SiC Thyristors with Differently Etched JTEs	1167
G. Pâques, S. Scharnholz, N. Dheilly, D. Planson and R.W. De Doncker	
High-Yield 4H-SiC Thyristors for Wafer-Scale Interconnection	1171
B. Nechay, M. Snook, H. Hearne, T. McNutt, V. Veliadis, S. Woodruff, R.S. Howell, D. Giorgi, J. White and S. Davis	
Bipolar Degradation in 4H-SiC Thyristors	1175
S.I. Soloviev, P.A. Losee, S. Arthur, Z. Stum, J.L. Garrett and A. Elasser	
Pulse Characterization of Optically Triggered SiC Thyristors	1179
N. Dheilly, G. Pâques, S. Scharnholz and D. Planson	
Evaluation of High Power Experimental SiC SGTO Devices for Pulsed Power Applications	1183
S. Lacouture, K. Lawson, S. Bayne, M. Giesslmann, H. O'Brien and C.J. Scozzie	

6.7 Sensors and Photodetectors

Characterization of Large Area 4H-SiC and 6H-SiC Capacitive Devices at 600 °C	1187
R.N. Ghosh and R. Loloe	
Development of High Temperature SiC Based Hydrogen/Hydrocarbon Sensors with Bond Pads for Packaging	1191
J.C. Xu, G.W. Hunter, L.Y. Chen, A.M. Biaggi-Labiosa, B.J. Ward, D. Lukco, J.M. Gonzalez III, P.S. Lampard, M.A. Artale and C.L. Hampton	
Laser-Doped SiC as Wireless Remote Gas Sensor Based on Semiconductor Optics	1195
G. Lim, T. Manzur and A. Kar	
Silicon Carbide Ultraviolet Photodetector Modeling, Design and Experiments	1199
A. Akturk, M. Dandin, A.V. Vert, S.I. Soloviev, P. Sandvik, S. Potbhare, N. Goldsman and P. Abshire	
4H-SiC P⁺N UV Photodiodes : A Comparison between Beam and Plasma Doping Processes	1203
S. Biondo, L. Ottaviani, M. Lazar, D. Planson, J. Duchaine, V. Le Borgne, M.A. El Khakani, F. Milesi, W. Vervisch, O. Palais and F. Torregrosa	
A Theoretical and Experimental Comparison of 4H- and 6H-SiC MSM UV Photodetectors	1207
J.K. Lim, L. Östlund, Q. Wang, W. Kaplan, S.A. Reshanov, A. Schöner, M. Bakowski and H.P. Nee	
Characterization of Poly-SiC Pressure Sensors for High Temperature and High Pressure Applications	1211
S. Jin, S. Rajgopal and M. Mehregany	
High Temperature Capacitive Pressure Sensor Employing a SiC Based Ring Oscillator	1215
R.D. Meredith, P.G. Neudeck, G.E. Ponchak, G.M. Beheim, M.C. Scardelletti, J.L. Jordan, L.Y. Chen, D.J. Spry, M.J. Krasowski and G.W. Hunter	

6.8 Systems and Circuits

High Temperature Silicon Carbide Power Modules for High Performance Systems	1219
A.B. Lostetter, J. Hornberger, B. McPherson, J. Bourne, R. Shaw, E. Cilio, W. Cilio, B. Reese, E. Heinrichs, T. McNutt and M. Schupbach	
10 kV SiC Power MOSFETs and JBS Diodes: Enabling Revolutionary Module and Power Conversion Technologies	1225
M.K. Das, D. Grider, S. Leslie, R. Raju, M. Schutten and A. Hefner	
SiC JFET Power Modules for Reliable 250°C Operation	1229
D.C. Sheridan, J.B. Casady, T. Autry, R. Aguirre, V. Lee, R.W. Johnson, M.J. Palmer and J. Scofield	
A Compact 5-nH One-Phase-Leg SiC Power Module for a 600V-60A-40W/cc Inverter	1233
K. Matsui, Y. Zushi, Y. Murakami, S. Tanimoto and S. Sato	
Performance of a 25kW 700V Galvanically Isolated Bidirectional DC-DC Converter Using 1.2kV Silicon Carbide MOSFETs and Schottky Diodes	1237
A.K. Jain, D. McIntosh, M. Jones and B. Ratliff	
Switching Losses in a SiC-Based DC-DC Multilevel Boost Converter	1241
O. Mostaghimi, N.G. Wright and A.B. Horsfall	
High Voltage SiC Schottky Diodes in Rectifiers for X-Ray Generators	1245
P. Lürkens, P. Guimaraes, P. Godignon and J. Millán	
SiC Solid-State Disconnect for High Power System Applications	1249
X.Q. Li, P. Alexandrov, L. Fursin, C. Dries and J.H. Zhao	

A 450°C High Voltage Gain AC Coupled Differential Amplifier	1253
J. Yang, J. Fraley, B. Western, M. Schupbach and A.B. Lostetter	
Bipolar Integrated OR-NOR Gate in 4H-SiC	1257
L. Lanni, R. Ghandi, C. Zetterling, B.G. Malm and M. Östling	
300C Capable Digital Integrated Circuits in SiC Technology	1261
A. Patil, N. Rao and V. Tilak	
Reliability of Silicon Carbide Integrated Circuits at 300°C	1265
A.V. Vert, E.A. Andarawis and C.P. Chen	
Direct Frequency Modulation of a High Temperature Silicon Carbide Oscillator	1269
D. Brennan, K. Vassilevski, N.G. Wright and A.B. Horsfall	

Chapter 7: Related Materials

7.1 Nanomaterials

Conversion of Si Nanowires into SiC Nanotubes	1275
M. Ollivier, L. Latu-Romain, E. Bano, A. Mantoux and T. Baron	
Growth of SiC Nanowires on Different Planes of 4H-SiC Substrates	1279
R.V.K.G. Thirumalai, B. Krishnan, I. Levin, A. Davydov, S.G. Sundaresan, J.N. Merrett and Y. Koshka	
Fabrication of Silicon Carbide Thin Film as a Stabilizing Layer for Improving the Stability of Porous Silicon Photodiodes	1283
N. Naderi and M.R. Hashim	

7.2 III-Nitrides

Low Defect Density Bulk AlN Substrates for High Performance Electronics and Optoelectronics	1287
B. Raghothamachar, R. Dalmau, B. Moody, H.S. Craft, R. Schlessler, J.Q. Xie, R. Collazo, M. Dudley and Z. Sitar	
Control of the Growth Habit in the Na Flux Growth of GaN Single Crystals	1291
M. Imade, Y. Konishi, H. Takazawa, K. Murakami, H. Imabayashi, Y. Todoroki, A. Kitamoto, D. Matsuo, M. Maruyama, M. Yoshimura, Y. Kitaoka, T. Sasaki and Y. Mori	
Evolution of Structural and Electrical Properties of Au/Ni Contacts onto P-GaN after Annealing	1295
G. Greco, F. Roccaforte, R. Lo Nigro, C. Bongiorno, S. Di Franco, P. Prystawko, M. Leszczyński and V. Raineri	
Large GaN p-n Junction Diodes of 3 mm in Diameter on Free-Standing GaN Substrates with High Breakdown Voltage	1299
K. Nomoto, T. Nakamura, N. Kaneda, T. Kawano, T. Tsuchiya and T. Mishima	
Performance Comparison of GaN Power Transistors and Investigation on the Device Design Issues	1303
C.Y. Lee, Y.H. Chen, L.S. Lee, C.C. Hung, C.T. Yen, S.F. Lin, R. Xuan, W.H. Kuo, T.K. Ku and M.J. Tsai	
Design of High-Performance Synchronous Buck DC-DC Converters Using GaN Power HEMTs	1307
K. Shenai and K. Shah	

7.3 Diamond

Density Functional Simulations of Transition Metal Terminated (001)-Diamond Surfaces	1311
A.K. Tiwari, J.P. Goss, P.R. Briddon, N.G. Wright and A.B. Horsfall	
Electrical Characterisation of Defects in Polycrystalline B-Doped Diamond Films	1315
O.S. Elsherif, K.D. Vernon-Parry, J.H. Evans-Freeman and P.W. May	
Diamond Vertical Schottky Barrier Diode with Al₂O₃ Field Plate	1319
H. Umezawa, M. Nagase, Y. Kato and S. Shikata	

7.4 n-ZnO/p-SiC Heterojunctions, Novel Nitride Semiconductors

Fabrication and Characterization of n-ZnO/p-SiC Heterojunction Diode

M. Guziewicz, W. Jung, R. Kruszka, J. Domagala, A.B. Piotrowska, K. Gołaszewska, L. Wachnicki, E. Guziewicz and M. Godlewski

1323

Effects of Substrate Temperature on the Electrical and the Optical Properties of N-Type ZnO/P-Type 4H-SiC

J.C. Jung, J.H. Kim, K.M. Do, B.M. Moon, S.J. Joo, W. Bahng, S.C. Kim, N.K. Kim and S.M. Koo

1327

CdGeN₂ and ZnGe_{0.5}Sn_{0.5}N₂: Two New Nitride Semiconductors with Band Gaps in the Blue-Green

A. Punya and W.R.L. Lambrecht

1331