

Table of Contents

Preface

Chapter 1: Growth and Wafer Manufacturing

1.1: Bulk Crystal Growth

Fast 4H-SiC Bulk Growth by High-Temperature Gas Source Method Y. Tokuda, N. Hoshino, H. Kuno, H. Uehigashi, T. Okamoto, T. Kanda, N. Ohya, I. Kamata and H. Tsuchida	5
Development of 150-mm 4H-SiC Substrates Using a High-Temperature Chemical Vapor Deposition Method T. Okamoto, T. Kanda, Y. Tokuda, N. Ohya, K. Betsuyaku, N. Hoshino, I. Kamata and H. Tsuchida	14
Investigation of Carbon Inclusions in SiC Crystals Grown by PVT Method X.J. Xie, J.Y. Yu, X.L. Yang, X.F. Chen, X.G. Xu, X.B. Hu, X.T. Liu and D. Liu	20
Crystal Separation Method of 6-Inch 4H-SiC Crystal Using Adhesion Shrinkage between a Seed and a Seed Holder in Cooling Process J.H. Park, B.K. Jang, J.W. Choi, E. Yang, J.G. Kim, S.K. Ko, M.O. Kyun, K.R. Ku, D.S. Kim and W.J. Lee	26
Modified Hot-Zone Design of Growth Cell for Reducing the Warpage of 6"-SiC Wafer B.K. Jang, J.H. Park, J.W. Choi, E. Yang, J.G. Kim, S.K. Ko, M.O. Kyun, K.R. Ku, Y.S. Jang and W.J. Lee	32
Progress in Bulk 4H SiC Crystal Growth for 150 mm Wafer Production I. Manning, Y. Matsuda, G. Chung, E. Sanchez, M. Dudley, T. Ailihumaer and B. Raghothamachar	37
Investigation of Dislocation Behavior at the Early Stage of PVT-Grown 4H-SiC Crystals T. Ailihumaer, B. Raghothamachar, M. Dudley, G. Chung, I. Manning and E. Sanchez	44
Investigation on the Threading Dislocations Formed by Lattice Misfits during Initial Stage of Sublimation Growth of 4H-SiC T.H. Eun, I.G. Yeo, J.Y. Kim, S.S. Lee, H.S. Seo, M.C. Chun and S.K. Hong	51
An Approach to Predict 4H-SiC Wafer Bending after Back Side Thinning by Substrate Resistivity Analysis N. Piluso, S. Rinaldi, S. Lorenti, A. Bassi, A. Severino and S. Coffa	57
X-Ray Topography Characterization of Large Diameter AlN Single Crystal Substrates R. Dalmau, J. Britt, H.Y. Fang, B. Raghothamachar, M. Dudley and R. Schlessner	63

1.2: Epitaxial and Thin Film Growth

Highly Reliable 4H-SiC Epitaxial Wafer with BPD Free Recombination-Enhancing Buffer Layer for High Current Applications H. Itoh, T. Enokizono, T. Miyase, T. Hori, K. Wada, H. Doi and M. Furumai	71
Improvement of Repeatability on N-Type 4H-SiC Epitaxial Growth by High Speed Wafer Rotation Vertical CVD Tool Y. Daigo, A. Ishiguro, S. Ishii, T. Kobayashi and Y. Moriyama	78
Achievement of Low Carrier Concentration of High-Uniformity SiC Films Grown by High Speed Wafer Rotation Vertical CVD Tool Y. Daigo, A. Ishiguro, S. Ishii, T. Kobayashi and Y. Moriyama	84
Origin of Large Bumps Abnormally Grown on 4H-SiC Epitaxial Film by Adding HCl Gas with High Cl/Si Ratio in CVD Process Y. Daigo and A. Ishiguro	91
Revisiting the Site-Competition Doping of 4H-SiC: Cases of N and Al G. Ferro and D. Chaussende	96

Corona Assisted Tuning of Gallium Oxide Growth on 3C-SiC(111)/Si(111) Pseudosubstrates	102
J. Reiprich, N.A. Isaac, L. Schlag, M. Hopfeld, J. Pezoldt and H.O. Jacobs	

1.3: Growth of 3C-SiC Layer

Prospects of Bulk Growth of 3C-SiC Using Sublimation Growth	
P.J. Wellmann, P. Schuh, M. Kollmuss, M. Schöler, J. Steiner, M. Zielinski, M. Mauceri and F. La Via	113
3C-SiC Bulk Growth: Effect of Growth Rate and Doping on Defects and Stress	
F. La Via, M. Mauceri, V. Scuderi, C. Calabretta, M. Zimbone and R. Anzalone	120
Analysis of Defect-Free Hot Filament CVD-Grown 3C-SiC	
B. Van Zeghbroeck, R. Brow, T. Borsa and D. Bobela	126
Exploration of Solid Phase Epitaxy of 3C-SiC on Silicon	
M. Zielinski, S. Monnoye, H. Mank, F. Torregrosa, G. Grosset, Y. Spiegel, M. Portail and A. Michon	132
Mono-Versus Poly-Crystalline SiC for Nuclear Applications	
X. Huang, T. Yeghoyan, S. Gavarini, V. Soulière, N. Millard-Pinard and G. Ferro	139
Microscopic Identification of Surface Steps on SiC by Density-Functional Calculations	
K. Seino and A. Oshiyama	145

1.4: Etching and Wafer Machining

Reducing On-Resistance for SiC Diodes by Thin Wafer and Laser Anneal Technology	155
O. Rusch, C. Hellinger, J. Moult, Y. Corcoran and T. Erlbacher	
Cause of Etch Pits during the High Speed Plasma Etching of Silicon Carbide and an Approach to Reduce their Size	
Y. Nakanishi, R. Mukai, S. Matsuyama, K. Yamauchi and Y. Sano	161
Non-Plasma Dry Etcher Design for 200 mm-Diameter Silicon Carbide Wafer	
R. Kawasaki, K. Irikura, H. Habuka, Y. Takahashi and T. Kato	167
Etching Rate Profile of C-Face 4H-SiC Wafer Depending on Total Gas Flow Rate of Chlorine Trifluoride and Nitrogen	
K. Irikura, R. Kawasaki, H. Habuka, Y. Takahashi and T. Kato	173
Chemical Behavior of Byproduct Layer in Exhaust Tube Formed by Silicon Carbide Epitaxial Growth in a System Using Chlorides	
I. Mizushima and H. Habuka	180
SiC Epitaxial Reactor Cleaning by ClF₃ Gas with the Help of Reaction Heat	
K. Kurashima, M. Hayashi, H. Habuka, H. Ito, S.I. Mitani and Y. Takahashi	186
Cost-Efficient High-Throughput Polishing of Silicon Carbide Seed Crystals	
A. Titov, A. Walters, H. Sasai and T. Shindo	193
A New Permanganate-Free Slurry for GaN-SiC CMP Applications	
T. Fang, P.C. Chen and M.H. Lee	199
Direct Bonding of Diamond Substrate at Low Temperatures under Atmospheric Condition	
T. Matsumae, Y. Kurashima, H. Umezawa and H. Takagi	206

Chapter 2: Characterization and Defect Engineering

2.1: Fundamental and Characterization

Anomalous Temperature Dependence of the Hall Coefficient of Heavily Al-Doped 4H-SiC Epilayers in the Band Conduction Region	
H. Matsuura, R. Nishihata, A. Takeshita, K. Ogawa, T. Imamura, K. Takano, K. Okuda, A. Hidaka, S. Ji, K. Eto, K. Kojima, T. Kato, S. Yoshida and H. Okumura	215

Anomalous Conduction between the Band and Nearest-Neighbor Hopping Conduction Regions in Heavily Al-Doped p-Type 4H-SiC	224
A. Hidaka, A. Takeshita, K. Ogawa, T. Imamura, K. Takano, K. Okuda, H. Matsuura, S. JI, K. Eto, T. Mitani, K. Kojima, T. Kato, S. Yoshida and H. Okumura	
Comparative Results of Low Temperature Annealing of Lightly Doped N-Layers of Silicon Carbide Irradiated by Protons and Electrons	231
V.V. Kozlovski, O. Korolkov, A.A. Lebedev, J. Toompuu and N. Sleptsuk	
Improved High Precision Dopant/Carrier Concentration Profiling with Corona-Charge Non-Contact C-V (CnCV)	237
A. Savtchouk, M. Wilson, J. D'Amico, C. Almeida and J. Lagowski	
Wurtzite SiC Formation in Plastic Deformed 3C and 6H	243
J. Pezoldt and A.A. Kalnin	
Evaluation of p-Type 4H-SiC Piezoresistance Coefficients in (0001) Plane Using Numerical Simulation	249
T. Sugiura, N. Takahashi and N. Nakano	
SiC Natural and Artificial Superlattices for the Implementation of the Bloch Oscillation Process: A Comparative Analysis	256
V.I. Sankin, A.G. Petrov, P.P. Shkrebyi, O.P. Kazarova and A.A. Lebedev	
Photoluminescence Characterization of Fluorescent Sic with High Boron and Nitrogen Concentrations	265
D. Tanaka, W.F. Lu, S. Kamiyama, M. Iwaya, T. Takeuchi and I. Akasaki	
Resistivity Measurement of P⁺-Implanted 4H-SiC Samples Prepared at Different Implantation and Annealing Temperatures Using Terahertz Time-Domain Spectroscopic Ellipsometry	272
K. Ishiji, S. Kawado, Y. Hirai and S. Nagamachi	
Investigation of the Influence of Structural Defects on the PL Spectra in n-3C-SiC	278
L.V. Shakhev, A.A. Lebedev, N.V. Seredova, S.P. Lebedev, V.V. Kozlovski, A.V. Zubov and I.P. Nikitina	
Quantitative Characterization of Surface Polarity Dependence of Wetting Properties of V-Doped SiC Using a Novel Image Analysis Technique	284
J.G. Kim, W.S. Yoo, D.S. Kim and W.J. Lee	
Interest of Using a Micro-Meter Spatial Resolution to Study SiC Semi-Conductor Devices by Optical Beam Induced Current (OBIC)	290
C. Sonneville, D. Planson, L.V. Phung, P. Bevilacqua and B. Asllani	
Influence of Shallow Pits and Device Design of 4H-SiC VDMOS Transistors on In-Line Defect Analysis by Photoluminescence and Differential Interference Contrast Mapping	299
M. Kocher, H. Schlichting, B. Kallinger, M. Rommel, A.J. Bauer and T. Erlbacher	
A New Technique for Analyzing Defects in Silicon Carbide Devices: Electrically Detected Electron Nuclear Double Resonance	306
R.J. Waskiewicz, B. Manning, D.J. McCrory and P.M. Lenahan	
Review and Detail Classification of Stacking Faults in 4H-SiC Epitaxial Layer by Mirror Projection Electron Microscopy	314
K. Ohira, T. Isshiki, H. Sako, M. Hasegawa, K. Kobayashi and K. Onuki	
From Wafers to Bits and Back again: Using Deep Learning to Accelerate the Development and Characterization of SiC	321
R. Leonard, M. Conrad, E. Van Brunt, J. Giles, E. Hutchins and E. Balkas	

2.2: Point Defects and Quantum Technologies

Current-Mode Deep Level Spectroscopy of Vanadium-Doped HPSI 4H-SiC	331
G. Alfieri, L. Kranz and A. Mihaila	
Enhancement of ODMR Contrasts of Silicon Vacancy in SiC by Thermal Treatment	337
Y. Chiba, Y. Yamazaki, S.I. Sato, T. Makino, N. Yamada, T. Satoh, Y. Hijikata and T. Ohshima	
Optically Detected Magnetic Resonance Study of 3D Arrayed Silicon Vacancies in SiC pn Diodes	343
Y. Yamazaki, Y. Chiba, S.I. Sato, T. Makino, N. Yamada, T. Satoh, K. Kojima, Y. Hijikata, H. Tsuchida, N. Hoshino, S.Y. Lee and T. Ohshima	

Effects of Nitrogen Impurity Concentration on Nitrogen-Vacancy Center Formation in 4H-SiC	
T. Narahara, S.I. Sato, K. Kojima, Y. Yamazaki, Y. Hijikata and T. Ohshima	349
Near Infrared Photoluminescence of N_CV_{Si}⁻ Centers in High-Purity Semi-Insulating 4H-SiC Irradiated with Energetic Charged Particles	
S.I. Sato, T. Narahara, S. Onoda, Y. Yamazaki, Y. Hijikata, B.C. Gibson, A. Greentree and T. Ohshima	355
The Effect of γ-Ray Irradiation on Optical Properties of Single Photon Sources in 4H-SiC MOSFET	
Y. Abe, T. Umeda, M. Okamoto, S. Harada, Y. Yamazaki and T. Ohshima	361

2.3: Extended Defects

4H-SiC Epi-Ready Substrate Qualification by Using Mirror Electron Microscope Inspection System	
M. Hasegawa, K. Ohira, N. Kaneoka, T. Ogata, K. Onuki, K. Kobayashi, T. Osanai, K. Masumoto and J. Senzaki	369
Photoluminescence Analysis of Individual Partial Dislocations in 4H-SiC Epilayers	
J. Nishio, A. Okada, C. Ota and M. Kushibe	376
Characterization and Reduction of Defects in 4H-SiC Substrate and Homo-Epitaxial Wafer	
L. Yang, L.X. Zhao, H.W. Wu, Y. Liu, T. Ailihumaer, B. Raghorthamachar and M. Dudley	387
Synchrotron X-Ray Topography Study on the Relationship between Local Basal Plane Bending and Basal Plane Dislocations in PVT-Grown 4H-SiC Substrate Wafers	
T. Ailihumaer, H.Y. Peng, B. Raghorthamachar, M. Dudley, G. Chung, I. Manning and E. Sanchez	393
BPD-TED Conversion in the SiC Substrate after High-Temperature Si-VE	
Y. Sudoh, M. Kitabatake and T. Kaneko	401
Dislocations Analysis on Implanted (p-Type and n-Type) 4H-SiC Epi-Layer by KOH Molten Etching	
R. Anzalone, A. Severino, N. Piluso and S. Coffa	408
TEM Studies on the Microstructure of m-Face Grown 4H-SiC by Solution Growth	
J. Takahashi, K. Kawaguchi, K. Kusunoki, T. Ueyama and K. Kamei	414
Structural Characterization of Prismatic Stacking Faults of Two Types of Carrot Defects in 4H-SiC Epi Wafers	
H. Sako, K. Ohira, K. Kobayashi and T. Isshiki	421
Formation of Double Shockley Stacking Faults in Heavily Nitrogen Doped 4H-SiC Crystal with Reduction of Residual Stress around Scratch Damage	
N. Sugiyama, T. Mitani, I. Kamata, T. Kato, H. Tsuchida and H. Okumura	427
Nanoscale Insights on the Origin of the Power MOSFETs Breakdown after Extremely Long High Temperature Reverse Bias Stress	
P. Fiorenza, M.S. Alessandrino, B. Carbone, C. Di Martino, A. Russo, M. Saggio, C. Venuto, E. Zanetti, C. Bongiorno, F. Giannazzo and F. Roccaforte	433
Evaluation of Suppressing Forward Voltage Degradation by Using a Low BPD Density Substrate or an Epitaxial Wafer with an HNDE	
Y. Nishihara, K. Kamei, K. Momose and H. Osawa	439
Crystalline Quality Evaluation of SiC p/n Column Layers Formed by Trench-Filling-Epitaxial Growth	
K. Adachi, R. Kosugi, S. Ji, Y. Kawada, H. Fujisawa, S. Tomohisa, N. Miura, Y. Yonezawa and H. Okumura	445
Investigation of Dislocations Inducing Leakage Current on SiC Junction Barrier Schottky Diode by Two-Photon-Excited Band-Edge Photoluminescence	
Y. Nakanishi, T. Noguchi, T. Nakamura, M. Ikegami, K. Kobayashi, K. Konishi and K. Ebihara	451
Statistical Analysis of Killer and Non-Killer Defects in SiC and the Impacts to Device Performance	
H. Das, S. Sunkari, J. Justice, H. Pham, G. Park and Y.H. Seo	458
Investigation of Bipolar Degradation of 1.2 kV BJTs under Different Current and Temperature Conditions	
S. Rugen, S.G. Sundaresan, R. Singh and N. Kaminski	464

Impact of Threading Dislocations Detected by KOH Etching on 4H-SiC 650 V MOSFET Device Failure after Reliability Test

A. Severino, R. Anzalone, N. Piluso, E. Vitanza, B. Carbone, A. Russo and S. Coffa

472

2.4: Novel Materials and New Concepts

Evolution of SiO_x Shell Layers on SiC-SiO_x Core-Shell Nanowires

A. Broggi, E. Ringdalen and M. Tangstad

479

Nano- and Micro-Scale Simulations of Ge/3C-SiC and Ge/4H-SiC NN-Heterojunction Diodes

M.H. Rashid, A. Koel and T. Rang

490

Defects Characterization of GaN Substrate with Hot Implant Process

J. Maekawa, H. Kawanowa, M. Aoki, K. Takahiro and T. Isshiki

497

Structural Characterization of a Ga₂O₃ Epitaxial Layer Grown on a Sapphire Substrate Using Cross-Sectional and Plan-View TEM/STEM Analysis

A. Hashimoto, H. Sako, J. Sameshima, M. Nakamura, T. Kobayashi, S. Motoyama and Y. Otsuka

505

AFM Observation of Etch-Pit Shapes on β-Ga₂O₃ (001) Surface Formed by Molten Alkali Etching

K. Ogawa, N. Ogawa, R. Kosaka, T. Isshiki, T. Aiso, M. Iyoki, Y.Z. Yao and Y. Ishikawa

512

Dislocation Vector Analysis Method of Deep Dislocation Having C-Axis Segment in Diamond

S. Shikata and N. Akashi

519

Graphene Quality Assessment Using an Entropy Approach of SEM Images

B. Hähnlein, S.P. Lebedev, I.A. Eliseyev, V.Y. Davydov, A.A. Lebedev and J. Pezoldt

525

Chapter 3: MOS Gate Stacks and Device Processing

3.1: MOS Processing

Pre-Deposition Interfacial Oxidation and Post-Deposition Interface Nitridation of LPCVD TEOS Used as Gate Dielectric on 4H-SiC

M.W. Lim, T. Sledziewski, M. Rommel, T. Erlbacher, H.K. Kim, S.J. Kim, H.K. Shin and A.J. Bauer

535

Surface Treatment of 4H-SiC MOSFETs Prior to Al₂O₃ Deposition

M.I. Idris and A.B. Horsfall

541

Development of High-Quality Gate Oxide on 4H-SiC Using Atomic Layer Deposition

A.B. Renz, O.J. Vavasour, P.M. Gammon, F. Li, T.X. Dai, S. Esfahani, G.W.C. Baker, N.E. Grant, J.D. Murphy, P.A. Mawby and V.A. Shah

547

Effect of Phosphorus Doped Poly Annealing on Threshold Voltage Stability and Thermal Oxide Reliability in 4H-SiC MOSFET

K. Lee, Y.H. Seo, T. Lee, K.S. Park, M. Domeij, F. Allerstam and T. Neyer

554

4H-SiC Power VDMOSFET Manufacturing Utilizing POCl₃ Post Oxidation Annealing

Y. Ju, D. Bouvet, R. Stark, J. Woerle and U. Grossner

559

Compatibility of POCl₃ Gate Process with the Fabrication of Vertical 4H-SiC MOSFETs

T. Watanabe, M. Noguchi, S. Tomohisa and N. Miura

565

3.2: MOS Characterization

Wafer-Level near Zero Field Spin Dependent Charge Pumping: Effects of Nitrogen on 4H-SiC MOSFETs

M.A. Anders, P.M. Lenahan and J.T. Ryan

573

Low-Energy Muons as a Tool for a Depth-Resolved Analysis of the SiO₂/4H-SiC Interface

J. Woerle, T. Prokscha and U. Grossner

581

Profiling with Depth Resolution of Sub-nm for SiO₂/ SiC Interface by Dual-Beam TOF-SIMS Combined with Simulation

J. Sameshima, A. Takenaka, Y. Muraji, Y. Nakata and M. Yoshikawa

587

Monitoring on Creation and Annihilation of Interface Trap Levels with NO Oxidation, Re-Oxidation and N₂ Annealing with Conductance Measurements	
X. Zhou, C.W. Hitchcock, R.P. Dahal, G. Pandey, J. Kupernik, I. Bhat and T.P. Chow	595
Photo-Assisted Corona-Charge Characterization of Wide Bandgap Interfaces with Deep Traps Invisible in Standard C-V	
A. Savtchouk, M. Wilson, J. D'Amico, C. Almeida, A. Hoff and J. Lagowski	601
Evaluation of Interface Traps Type, Energy Level and Density of SiC MOSFETs by Means of C-V Curves TCAD Simulations	
I. Matacena, L. Maresca, M. Riccio, A. Irace, G. Breglio and S. Daliento	608
Gate Capacitance and Conductance-Voltage Characteristics of Vertical 4H-SiC MOSFETs	
X. Zhou, C.W. Hitchcock, P. Tang, I. Bhat and T.P. Chow	614
Insight into Channel Conduction Mechanisms of 4H-SiC(0001) MOSFET Based on Temperature-Dependent Hall Effect Measurement	
H. Takeda, M. Sometani, T. Hosoi, T. Shimura, H. Yano and H. Watanabe	620
Influence of Non-Uniform Interface Defect Clustering on Field-Effect Mobility in SiC MOSFETs Investigated by Local Deep Level Transient Spectroscopy and Device Simulation	
K. Yamasue, Y. Yamagishi and Y. Cho	627
A Comparison of Active Near-Interface Traps in Nitrided and As-Grown Gate Oxides by the Direct Measurement Technique	
P. Pande, S. Dimitrijev, D. Haasmann, H.A. Moghadam, P. Tanner and J.S. Han	635
Ultrafast Pulsed I-V and Charge Pumping Interface Characterization of Low-Voltage n-Channel SiC MOSFETs	
M. Ekström, B.G. Malm and C. Zetterling	642
Tunneling Effects in NH₃ Annealed 4H-SiC Trench MOSFETs	
J. Berens, G. Pobegen and T. Grasser	652
Reliability Study of MOS Capacitors Fabricated on 3C-SiC/Si Substrates	
F. Li, S. Qiu, M. Jennings and P.A. Mawby	659
TDDB Lifetime Enhancement in SiC-MOSFETs under Gate-Switching Operation	
E. Murakami, T. Takeshita and K. Oda	665
Modeling of Threshold Voltage Hysteresis in SiC MOSFET Device	
S. Cascino, M. Saggio and A. Guarnera	671

3.3: Device Processing

3× 10¹⁸ - 1 × 10¹⁹ cm⁻³ Al⁺ Ion Implanted 4H-SiC: Annealing Time Effect	
R. Nipoti, A. Parisini, V. Boldrini, S. Vantaggio, M. Canino, M. Sanmartin and G. Alfieri	683
Intentional and Unintentional Channeling during Implantation of p-Dopants in 4H-SiC	
M.K. Linnarsson, A. Hallén and L. Vines	689
Ion Implanted Phosphorous for 4H-SiC VDMOSFETs Source Regions: Effect of the Post Implantation Annealing Time	
R. Nipoti, A. Parisini, V. Boldrini, S. Vantaggio, M. Gorni, M. Canino, G. Pizzochero, M. Camarda, J. Woerle and U. Grossner	698
4H-SiC MOSFET Source and Body Laser Annealing Process	
C. Calabretta, M. Agati, M. Zimbone, S. BONINELLI, A. Castiello, A. Pecora, G. Fortunato, L. Calcagno, L. Torrisi and F. La Via	705
The Ohmic Contact of 4H-SiC Power Devices by Pulse Laser Annealing and Rapid Thermal Annealing	
Z.W. Zhou, Z.Z. Zhang, W.W. He, J.Y. Hao, J. Sun, F. Zhang and Z.D. Zheng	712
Low-Resistance Ohmic Contact Formation by Laser Annealing of N-Implanted 4H-SiC	
C. Hellinger, O. Rusch, M. Rommel, A.J. Bauer and T. Erlbacher	718
Current Transport Mechanisms in Au-Free Metallizations for CMOS Compatible GaN HEMT Technology	
F. Roccaforte, M. Spera, S. Di Franco, R. Lo Nigro, P. Fiorenza, F. Giannazzo, F. Iucolano and G. Greco	725
Development of SiC Etching by Chlorine Fluoride Gas	
Y. Takahashi, K. Kato and H. Habuka	731
The Waffle Substrate: A Novel Approach to Reducing Substrate Resistance in SiC Power Devices	
N. Oondono, J.A. Cooper, H.J. Liao, W.N. Chen and D. Morissette	738

Chapter 4: Power Devices

4.1: MOSFETs

The IMOSFET: A Deeply-Scaled Fully-Self-Aligned Trench MOSFET	751
M. Sampath, A. Salemi, D. Morisette and J.A. Cooper	
Challenges in Extremely Low Specific On-Resistance with SiC SJ-VMOSFETs	758
T. Masuda, Y. Saito, T. Hatayama, H. Michikoshi, Y. Mikamura and S. Harada	
Effects of Grounding Bottom Oxide Protection Layer in Trench-Gate SiC-MOSFET by Tilted Al Implantation	764
Y. Fukui, K. Sugawara, R. Tanaka, H. Koketsu, H. Hatta, Y. Miyata, H. Suzuki, K. Taguchi, Y. Kagawa, S. Tomohisa and N. Miura	
Performance Improvement of Trench-Gate SiC MOSFETs by Localized High-Concentration N-Type Ion Implantation	770
R. Tanaka, K. Sugawara, Y. Fukui, H. Hatta, H. Koketsu, H. Suzuki, Y. Miyata, K. Taguchi, Y. Kagawa, S. Tomohisa and N. Miura	
1200 V / 200 A V-Groove Trench MOSFET Optimized for Low Power Loss and High Reliability	776
K. Uchida, T. Hiyoshi, Y. Saito, H. Egusa, T. Kaneda, H. Oomori and T. Tsuno	
Demonstration of Superior Static, Dynamic, and Short-Circuit Performance of 1.2 kV 4H-SiC Split-Gate Octagonal Cell MOSFETs Compared with Linear, Square, and Hexagonal Topologies	783
K.J. Han, A. Kanale, B.J. Baliga and S. Bhattacharya	
Experimental Study of Switching and Short-Circuit Performance of 1.2 kV 4H-SiC Accumulation and Inversion Channel Power MOSFETs	789
A. Agarwal, A. Kanale, K.J. Han, B.J. Baliga and S. Bhattacharya	
Highly Efficient Switching Operation of 1.2 kV-Class SiC SWITCH-MOS	795
M. Okada, T. Kumazawa, Y. Kobayashi, M. Baba and S. Harada	
Investigation on the Effect of Total Loss Reduction of HV Power Module by Using SiC-MOSFET Embedding SBD	801
T. Tominaga, S. Hino, Y. Mitsui, J. Nakashima, K. Kawahara, S. Tomohisa and N. Miura	
Design and Optimisation of Schottky Contact Integration in a 4H-SiC Trench MOSFET	808
T.X. Dai, A.B. Renz, L.Y. Zhang, O.J. Vavasour, G.W.C. Baker, V.A. Shah, P.A. Mawby and P.M. Gammon	
Investigation into the Body Diode Degradation of 6.5 kV SiC MOSFETs	814
E. Bianda, A. Mihaila, G. Romano, L. Knoll, S. Wirths and D. Torresin	
Commercialization of Highly Rugged 4H-SiC 3300 V Schottky Diodes and Power MOSFETs	822
A. Gendron-Hansen, C. Hong, Y.F. Jiang, J. May, D. Sdrulla, B. Odekirk and A.S. Kashyap	
Experimental Analysis of 600V 4H-SiC Vertical and Lateral MOSFETs Fabricated on the same 6-Inch Substrate Using a Single Process	830
N. Yun, J. Lynch and W.J. Sung	
Avalanche Ruggedness Assessment of 1.2kV 45mΩ Asymmetric Trench SiC MOSFETs	837
X.C. Deng, H. Zhu, X. Li, X.J. Xu, K. Zhou, Z.Q. Li, S. Bai, Y.R. Zhang and B. Zhang	
Influence of Aluminum Compensation Effects in 4H-SiC on the Performance of VDMOS Transistors	843
H. Schlichting, M. Kocher, J. Weisse, T. Erlbacher and A.J. Bauer	
SiC MOSFET with a Self-Aligned Channel Defined by Shallow Source-JFET Implantation: A Simulation Study	850
T. Sledziewski and T. Erlbacher	
Improved SiC MOSFET SPICE Model to Avoid Convergence Errors	856
H. Lefdal Hove, O.C. Spro, G. Guidi and D. Peftitsis	
Advanced TCAD Design Techniques for the Performance Improvement of SiC MOSFETs	865
M. Bellini and L. Knoll	

1.2 kV, 10 A, 4H-SiC Bi-Directional Field Effect Transistor (BiDFET) with Low On-State Voltage Drop

A. Kanale, T.H. Cheng, K.J. Han, B.J. Baliga, S. Bhattacharya and D. Hopkins 872

Common-Drain Bidirectional 1200V SiC MOSFETs

C.W. Hitchcock and T.P. Chow 882

Mechanisms of Heavy Ion-Induced Single Event Burnout in 4H-SiC Power MOSFETs

J.A. McPherson, C.W. Hitchcock, T.P. Chow, W. Ji and A.A. Woodworth 889

4.2: Bipolar Devices, JFETs and Diodes

20 kV-Class Ultra-High Voltage 4H-SiC n-IE-IGBTs

A. Koyama, Y. Kiuchi, T. Mizushima, K. Takenaka, S. Matsunaga, M. Sometani, K. Nakayama, H. Ishimori, A. Kimoto, M. Takei, T. Kato, Y. Yonezawa and H. Okumura 899

Experimental Demonstration of Ruggedness in 13 kV SiC-IGBT

K. Konishi, K. Hamada, H. Okabe, Y. Miyata, H. Niwa, K. Ebihara, K. Kawahara, N. Kawabata, S. Tomohisa and N. Miura 905

Wide-Range Prediction of Ultra-High Voltage SiC IGBT Static Performance Using Calibrated TCAD Model

D. Johannesson, K. Jacobs, S. Norrga, A. Hallén, M. Nawaz and H.P. Nee 911

Transient Performance of >10kV SiC IGBT with an Optimized Retrograde p-Well

A. Tiwari, M. Antoniou, T. Trajkovic, T.X. Dai, P.M. Gammon and F. Udrea 917

Static and Switching Characteristics of 10 kV-Class Silicon Carbide Bipolar Junction Transistors and Darlingtons

B. Asllani, P. Bevilacqua, H. Morel, D. Planson, L.V. Phung, B. Choucou, T. Lagier and M. Mermet-Guyennet 923

Short Circuit Ruggedness of 600 V SiC Trench JFETs

V. Sundaramoorthy, L. Kranz, S. Wirths, M. Bellini, G. Romano, Y. Arango, E. Bianda, L. Knoll and A. Mihaila 933

Dynamic Switching of 3kV 4H-SiC Charge-Balanced Junction Barrier Schottky (JBS) Diodes

X. Zhou, C.W. Hitchcock, R. Ghandi, A. Bolotnikov and T.P. Chow 939

A Subcircuit SPICE Model for SiC Charge-Balance Schottky Diodes

C.W. Hitchcock, X. Zhou, G. Pandey, R. Ghandi, A. Bolotnikov and T.P. Chow 945

Temperature Dependence of the Bipolar Activation and the Leakage Currents of 10 kV 4H-SiC JBS-Diodes

B. Lechner, Y. Huang, S. Schaub and G. Wachutka 953

Analysis of Barrier Inhomogeneities of P-Type Al/4H-SiC Schottky Barrier Diodes

M.H. Ziko, A. Koel, T. Rang and J. Toompuu 960

Chapter 5: Packaging and Applications

5.1: Packaging and Power Modules

Power Cycling Capability and Lifetime Estimation of Discrete Silicon Carbide Power Devices

F. Hoffmann and N. Kaminski 977

Stress Test of Cascode Switch Using SiC Static Induction Transistor

T. Matsumoto, Y. Tanaka and K. Yano 985

Accelerated Testing of SiC Power Devices under High-Field Operating Conditions

D.J. Lichtenwalner, S. Sabri, E. Van Brunt, B. Hull, S.H. Ryu, P. Steinmann, A. Romero, J.H. Park, S. Ganguly, D.A. Gajewski, J. Richmond, S. Allen and J.W. Palmour 992

Investigations on the Resistance Reduction Effect of Double-Trench SiC MOSFETs under Repetitive Avalanche Stress

J.X. Wei, S.Y. Liu, S. Li, L.Z. Tang, R.C. Lou, H. Fu, H.B. Zhao, W.F. Sun, X.B. Zhang and S. Bai 998

High-Temperature Reliability Analysis of 1200V/100A 4H-SiC Junction Barrier Schottky Diodes	Y.D. Tang, X.Y. Liu, C. Li, Y. Bai, H. Chen and C.Y. Yang	1004
Evaluation of SiC-MOSFET by Repetitive UIS Tests for Solid State Circuit Breaker	M. Sagara, K. Wada and S. Nishizawa	1010
High-Performance SIP Half-Bridge IPM Based on 35mΩ/1200V SiC Stack-Cascode	P. Alexandrov, A. Bhalla, X.Q. Li and J. Eltze	1016
Improving Heat Conduction of Insulated Metal Substrate with Thermal Pyrolytic Graphite Core for SiC Power Module Packaging	W. Fan, G. Wexler, E. Gurpinar and B. Ozpineci	1022
Effects of Pulsed and DC Body-Diode Current Stress on the Stability of 1200-V SiC MOSFET I-V Characteristics	R. Green, A. Lelis and F.L. Nouketcha	1027
High Temperature Gate Voltage Step-by-Step Test to Assess Reliability Differences in 1200 V SiC MOSFETs	E. Mengotti, E. Bianda, S. Wirths, D. Baumann, J. Bettega and J. Jormanainen	1033
The Study of Comparative Characterization between SiC MOSFET and Si- IGBT for Power Module and Three-Phase SPWM Inverter	H. Lee, C.K. Liu and T.C. Chang	1045

5.2: Circuits and Applications

Towards Making SiC ICs Durable and Accessible for Use in the Most Extreme Environments (Including Venus)	P.G. Neudeck and D.J. Spry	1057
New Insight into Single-Event Radiation Failure Mechanisms in Silicon Carbide Power Schottky Diodes and MOSFETs	A.F. Witulski, D.R. Ball, R.A. Johnson, K.F. Galloway, A.L. Sternberg, M.L. Alles, R.A. Reed, R.D. Schrimpf, J.M. Hutson, A. Javanainen, J. Lauenstein, D. Grider, D.J. Lichtenwalner, A. Raman and R. Arslanbekov	1066
Impact of Proton Irradiation on Power 4H-SiC MOSFETs	A.A. Lebedev, V.V. Kozlovski, L. Fursin, A.M. Strel'chuk, M.E. Levinshtein, P.A. Ivanov and A.V. Zubov	1074
Effect of Proton and Electron Irradiation on Current-Voltage Characteristics of Rectifying Diodes Based on 4H-SiC Structures with Schottky Barrier	A.M. Strel'chuk, V.V. Kozlovski and A.A. Lebedev	1081
Comparative Numerical Analysis of the Robustness of Si and SiC PiN Diodes Against Cosmic Radiation-Induced Failure	Y. Huang, B. Lechner and G. Wachutka	1088
Extreme Environment Integrated Circuits Based on Enhancement Mode SiC JFETs	P. Alexandrov and M. O'Grady	1097
Effect Irradiation with 15 MeV Protons on Properties of 4H- SiC UV Detectors	E.V. Kalinina, A.A. Lebedev, V.V. Kozlovski, V. Zabrodski, A. Nikolaev, M.Z. Shvarts and S. Levina	1104
Radiation Hardness of 4H-SiC JFETs in MGy Dose Ranges	A. Takeyama, K. Shimizu, T. Makino, Y. Yamazaki, S. Kuroki, Y. Tanaka and T. Ohshima	1109
High-Temperature Operating Characteristics of Inverter Using SBD-Integrated MOSFET	S. Sato, F. Kato, H. Hozoji, H. Sato, H. Yamaguchi and S. Harada	1115
Impact of Channel Implantation on a 4H-SiC CMOS Operational Amplifier for High Temperature Applications	M. Albrecht, D. Pérez, R.C. Martens, A.J. Bauer and T. Erlbacher	1123
Evaluation of Surge Reduction Performance of a SiC Avalanche Diode with Mesa Structure in a Switching Power Supply	K. Koseki, M. Yamamoto and Y. Tanaka	1129
Inrush Current Effects on SiC-MOSFETs for LLC Converter	Y. Takaku, H. Tanaka, Y. Takada and S. Nakata	1134
Development of a Pulsed Power Supply Utilizing 13 kV Class SiC-MOSFETs	K. Okamura, F. Naito, K. Takayama, H. Kitai, H. Michikoshi, K. Sakamoto, A. Tokuchi, T. Kaito and D. Kumamoto	1141

Experimental Study on Mitigation of Lifetime-Limiting Dielectric Cracking in Extreme Temperature 4H-SiC JFET Integrated Circuits

D.J. Spry, P.G. Neudeck and C.W. Chang

1148