

C. Y. Yang M. M. Rahman G. L. Harris (Eds.)

Amorphous and Crystalline Silicon Carbide IV

Proceedings of the 4th International Conference,
Santa Clara, CA, October 9–11, 1991

With 336 Figures

Springer-Verlag
Berlin Heidelberg New York
London Paris Tokyo
Hong Kong Barcelona
Budapest

Contents

Part I	Growth of Crystalline Silicon Carbide	
<hr/>		
Recent Progress in Epitaxial Growth of SiC By H. Matsunami (With 7 Figures)		3
Si _{1-y} C _y Alloys – Extending Si-Based Heterostructure Engineering By S.S. Iyer, K. Eberl, M.S. Goorsky, J.C. Tsang, F.K. LeGoues, F. Cardone, and B.A. Ek (With 8 Figures)		13
Investigation of the Growth of 3C-SiC and 6H-SiC Films on Low-Tilt-Angle Vicinal (0001) 6H-SiC Wafers By J.A. Powell, D.J. Larkin, J.B. Petit, and J.H. Edgar (With 4 Figures)		23
Low Temperature Homoepitaxial Growth of 6H-SiC by VPE Method By T. Kimoto, H. Nishino, A. Yamashita, W.S. Yoo, and H. Matsunami (With 4 Figures)		31
Heteroepitaxial Growth of 3C-SiC by LPCVD with Alternate Gas Supply By H. Nagasawa and Y. Yamaguchi (With 10 Figures)		40
Mechanisms in the Low Pressure Growth of SiC-on-Si by RTCVD By A.J. Steckl and J.P. Li (With 5 Figures)		49
Effects of CH ₃ Cl Gas on Heteroepitaxial Growth of β -SiC on Si(111) by Chemical Vapor Deposition By K. Ikoma, M. Yamanaka, H. Yamaguchi, and Y. Shichi (With 9 Figures)		60
Growth Simulation of SiC Polytypes and Application to DPB-Free 3C-SiC on Alpha-SiC Substrates By W.S. Yoo and H. Matsunami (With 7 Figures)		66
Epitaxial Growth of Cubic SiC Using Various Alkyl-Silicon Compounds by Chemical Vapor Deposition By K. Takahashi, S. Nishino, J. Saraie, and K. Harada (With 4 Figures)		78

Growth and Characterization of β -SiC Films Grown on Si by Gas-Source Molecular Beam Epitaxy By L.B. Rowland, S. Tanaka, R.S. Kern, and R.F. Davis (With 5 Figures)	84
Atomic Layer Control of β -SiC(001) Surface By S. Hara, Y. Aoyagi, M. Kawai, S. Misawa, E. Sakuma, and S. Yoshida (With 3 Figures)	90
Growth and Characterization of 6H-SiC Bulk Crystals by the Sublimation Method By K. Koga, Y. Fujikawa, Y. Ueda, and T. Yamaguchi (With 6 Figures)	96
Liquid Phase Epitaxy of SiC-AlN Solid Solutions By V.A. Dmitriev, L.B. Elfimov, I.Yu. Lin'kov, Ya.V. Morozenko, I.P. Nikitina, V.E. Chelnokov, A.E. Cherenkov, and M.A. Chernov (With 3 Figures)	101
Comparison of Dilutely Doped p-Type 6H-SiC from a Variety of Sources By L.L. Clemen, W.J. Choyke, R.P. Devaty, J.A. Powell, and H.-S. Kong (With 7 Figures)	105
Growth of Cubic Silicon Carbide on Silicon Using the C_2HCl_3 - SiH_4 - H_2 System By I.M. Baranov, V.A. Dmitriev, I.P. Nikitina, and T.S. Kondrateva (With 3 Figures)	116
AC Plasma-Assisted Chemical Vapor Deposition of Cubic Silicon Carbide on Silicon Substrate By H. Shimizu, K. Naito, and S. Ishio (With 7 Figures)	119

Part II Characterization of Crystalline Silicon Carbide

Hall Effect and Infrared Absorption Measurements on Nitrogen Donors in 6H-SiC By W. Suttrop, G. Pensl, W.J. Choyke, A. Dörnen, S. Leibenzeder, and R. Stein (With 4 Figures)	129
Nitrogen Impurities in 3C-SiC Epilayers By I. Nashiyama, S. Misawa, H. Okumura, S. Yoshida, and Y. Hirabayashi (With 5 Figures)	136
Electron Nuclear Double Resonance Investigations of Nitrogen Donors in 6H and 4H-SiC By S. Greulich-Weber, R. Müller, and J.-M. Spaeth	142
Recrystallization and Electrical Properties of High-Temperature Implanted (N,Al) 6H-SiC Layers By W. Suttrop, H. Zhang, M. Schadt, G. Pensl, K. Dohnke, and S. Leibenzeder (With 5 Figures)	143

EPR in the 2-mm Range and Optical Absorption of the Native Defect in 4H-SiC Epilayers By E.N. Kalabukhova, S.N. Lukin, B.D. Shanina, Yu.A. Vodakov, A.A. Lepneva, and E.N. Mokhov (With 4 Figures)	149
The Structure of the D-Center in Silicon Carbide – A Study with Electron Nuclear Double Resonance By S. Greulich-Weber, R. Müller, and J.-M. Spaeth	162
Oxidation Studies for 6H-SiC By C.S. Patuwathavithane, J.B. Crofton, J.R. Williams, C.C. Tin, Z.C. Feng, M.J. Bozack, P.A. Barnes, R. Ramesham, and C.D. Ellis (With 5 Figures)	163
Electronic Band Structures of SiC Calculated from a Hybrid Pseudopotential and Tight-Binding Model By P. Srichaikul, A.-B. Chen, and W.J. Choyke (With 2 Figures)	170
Metallization Studies on Epitaxial 6H-SiC By J. Crofton, J.M. Ferrero, P.A. Barnes, J.R. Williams, M.J. Bozack, C.C. Tin, C.D. Ellis, J.A. Spitznagel, and P.G. McMullin (With 4 Figures)	176
TEM Study of β -SiC Films Grown on (111) Silicon Substrates By K. Fekade, M.G. Spencer, S. Nahm, and L.G. Salamanca-Riba (With 6 Figures)	183
Thermal Oxidation of Single-Crystal Silicon Carbide: Kinetic, Electrical, and Chemical Studies By J.B. Petit, P.G. Neudeck, L.G. Matus, and J.A. Powell (With 9 Figures)	190
Determination of Stacking-Fault Abundances and Distributions in SiC Using XRPD and HRTEM By P.J. Schields	197
Structural Defects in Epitaxial Layers SiC-3C/Si Grown by CVD By R.N. Kyutt, I.P. Nikitina, S.S. Ruvimov, and D. Baither (With 4 Figures)	198
Observation of Linear Electro-Optic Effect in Cubic Silicon Carbide By X. Tang, K.G. Irvine, D. Zhang, and M.G. Spencer (With 3 Figures)	206
Optically Induced Near-IR Absorption Lines in 6H-SiC By Th. Stiasny, R. Helbig, and R.A. Stein (With 9 Figures)	210
Interference Fringes in the Infrared Reflectance of 6H-SiC Films on 6H-SiC Substrates By M.F. MacMillan, W.J. Choyke, and R.P. Devaty (With 3 Figures)	216

Low Temperature Photoluminescence of SiC: A Method for Material Characterization and the Influence of an Uniaxial Stress on the Spectra By Ch. Haberstroh, R. Helbig, and S. Leibenzeder (With 6 Figures)	221
--	-----

**Part III Growth and Characterization of Polycrystalline,
Microcrystalline, and Amorphous Silicon Carbide**

Novel Feedstocks for a-SiC:H Films By Y.-M. Li, B.F. Fieselmann, and A. Catalano (With 7 Figures)	229
Studies of 1,3-Disilacyclobutanes as Single-Source CVD Precursors to Silicon Carbide By D.J. Larkin and L.V. Interrante (With 3 Figures)	239
Frequency Dependence of Conductivity of Hydrogenated Amorphous SiC Films Prepared by PCVD By A. Tabata, K. Tomiita, Y. Suzuoki, and T. Mizutani (With 9 Figures)	245
Formation of SiC for Microelectronic Applications by C Implantation into Doped a-Si By B.M. Manning, S.B. Hewitt, N.G. Tarr, and T.W. MacElwee (With 5 Figures)	252
Polycrystalline SiC Films Prepared by a Plasma Assisted Method at Temperatures Lower than 1000°C By K. Kamimura, K. Koike, H. Ono, T. Homma, Y. Onuma, and S. Yonekubo (With 4 Figures)	259
Si _x C _{1-x} Alloys Deposited on Silicon Using a Low-Cost, Hot-Wall, LPCVD Reactor By F. Hébert (With 4 Figures)	266
Low Temperature PECVD Growth and Characterization of a-SiC:H Films Deposited from Silacyclobutane and Silane/Methane Precursor Gases By M.J. Loboda (With 5 Figures)	271
Study of Optimum Condition for Microcrystalline SiC Film Formation by ECR Plasma CVD Method By T. Miyajima, K. Sasaki, and S. Furukawa (With 5 Figures)	281

Part IV Applications

Applications for 6H-Silicon Carbide Devices By J.W. Palmour, J.A. Edmond, H.-S. Kong, and C.H. Carter, Jr. (With 6 Figures)	289
HBTs Using a-SiC and μ C-Si By S. Furukawa and K. Sasaki (With 8 Figures)	298

Impact of SiC on Power Devices By B.J. Baliga (With 7 Figures)	305
SiC _x :F Hetero-Emitter and Epitaxial-Base Bipolar Transistors By T. Sugii, T. Yamazaki, Y. Arimoto, T. Ito, I. Namura, H. Goto, and A. Tahara (With 15 Figures)	314
A New Application of a-SiC Films for Realizing High Current Gain Si Heterojunction Bipolar Transistors By K. Sasaki, T. Miyajima, and S. Furukawa (With 4 Figures)	322
The Development of ECR-CVD SiC Coatings for X-Ray Mask Membranes By A.R. Shimkunas, P.E. Mauger, L.P. Bourget, R.S. Post, L. Smith, R.F. Davis, G.M. Wells, F. Cerrina, J.E. Butler, and R.B. McIntosh	326
Pattern Etching of Crystalline SiC by KrF Excimer Laser By K. Shirakawa and M. Murahara (With 13 Figures)	328
Electrical Characterization of PiN Diode Structures in 6H-SiC By C.T. Gardner, J.A. Cooper, Jr., M.R. Melloch, J.W. Palmour, and C.H. Carter, Jr. (With 8 Figures)	338
High-Temperature Rectifiers, UV Photodiodes, and Blue LEDs in 6H-SiC By J.A. Edmond, H.-S. Kong, and C.H. Carter, Jr. (With 5 Figures)	344
Dependence of the Au-SiC(6H) Schottky Barriers Height on the SiC Surface Treatment By V.A. Dmitriev, K. Fekade, and M.G. Spencer (With 3 Figures)	352
Photoelectrochemical Etching and Dopant Selective Etch-Stops in SiC By J.S. Shor, X.G. Zhang, A.D. Kurtz, and R.M. Osgood, Jr. (With 4 Figures)	356
Fabrication and Electrical Properties of β -SiC/Si and Poly-SiC/Si Solar Cells By A. Solangi and M.I. Chaudhry (With 3 Figures)	362
Simulations of Ge and C Implantations to Form Si _{1-x} Ge _x BJT By A. Gupta, J.W. Waters, M.M. Rahman, and C.Y. Yang (With 5 Figures)	368
The Light Emitting Diodes on the Basis of Fast Electron Irradiated Silicon Carbide By Yu.A. Vodakov, A.I. Girka, A.O. Konstantinov, E.N. Mokhov, A.D. Roenkov, S.V. Svirida, V.V. Semenov, V.I. Sokolov, and A.V. Shishkin (With 4 Figures)	374
Graded-Gap and Quantum-Well Injection a-SiC:H p-i-n Light-Emitting Diodes By Jyh-Wong Hong, Tean-Sen Jen, Sui-Liang Ning, Nerng-Fu Shin, and Chun-Yen Chang (With 5 Figures)	381

High-Temperature and High-Voltage Diamond Devices By H. Shiomi, Y. Nishibayashi, and N. Fujimori (With 7 Figures)	387
Gamma-Ray Irradiation Effects on Cubic Silicon Carbide Metal-Oxide-Semiconductor Structure By M. Yoshikawa, Y. Morita, H. Itoh, I. Nashiyama, S. Misawa, H. Okumura, and S. Yoshida (With 4 Figures)	393
Formation of SiGe/Si Heterostructures by Low-Temperature Germanium Ion Implantation By K. Shoji, A. Fukami, T. Nagano, T. Tokuyama, A. Gupta, and C.Y. Yang (With 4 Figures)	399
Characterization of Ge and C Implanted Si Diodes By C. Cook, A. Gupta, and C.Y. Yang (With 3 Figures)	405
Selective Growth of SiC and Application to Heterojunction Devices By S. Nishino, H. Tanaka, K. Takahashi, and J. Saraie (With 5 Figures)	411
Electrical Characterization of Epitaxial Titanium Contacts to Alpha (6H) Silicon Carbide By L.M. Spellman, R.C. Glass, R.F. Davis, T.P. Humphreys, R.J. Nemanich, K. Das, and S. Chevacharoenkul (With 8 Figures)	417
Effect of H ₂ Additive on Reactive Ion Etching of β -SiC in CHF ₃ /O ₂ Plasma By A.J. Steckl and P.H. Yih (With 5 Figures)	423
Index of Contributors	431