

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:

Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature

Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer

Frontmatter

[More information](#)

**Wide-Bandgap Semiconductors
for High Power, High Frequency
and High Temperature**

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter

[More information](#)

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter

[More information](#)

**MATERIALS RESEARCH SOCIETY
SYMPOSIUM PROCEEDINGS VOLUME 512**

Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature

Symposium held April 13–15, 1998, San Francisco, California, U.S.A.

EDITORS:

Steven DenBaars

*University of California
Santa Barbara, California, U.S.A.*

John Palmour

*Cree Research, Inc.
Durham, North Carolina, U.S.A.*

Michael Shur

*Rensselaer Polytechnic Institute
Troy, New York, U.S.A.*

Michael Spencer

*Howard University
Washington, D.C., U.S.A.*



Materials Research Society
Warrendale, Pennsylvania

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter

[More information](#)

CAMBRIDGE UNIVERSITY PRESS

Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Mexico City

Cambridge University Press

32 Avenue of the Americas, New York NY 10013-2473, USA

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org

Information on this title: www.cambridge.org/9781107413641

Materials Research Society

506 Keystone Drive, Warrendale, PA 15086

<http://www.mrs.org>

© Materials Research Society 1998

This publication is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without the written
permission of Cambridge University Press.

This publication has been registered with Copyright Clearance Center, Inc.
For further information please contact the Copyright Clearance Center,
Salem, Massachusetts.

First published 1998

First paperback edition 2013

Single article reprints from this publication are available through
University Microfilms Inc., 300 North Zeeb Road, Ann Arbor, MI 48106

CODEN: MRSPDH

ISBN 978-1-107-41364-1 Paperback

Cambridge University Press has no responsibility for the persistence or
accuracy of URLs for external or third-party internet websites referred to in
this publication, and does not guarantee that any content on such websites is,
or will remain, accurate or appropriate.

Cambridge University Press
978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter
[More information](#)

CONTENTS

Preface xiii

Materials Research Society Symposium Proceedings xiv

PART I: GaN MATERIALS AND DEVICES

***GaN Materials for High-Power
Microwave Amplifiers** 3
*Lester F. Eastman, Kenneth Chu, Joseph Smart,
and J. Richard Shealy*

**Double-Channel AlGaIn/GaN Heterostructure
Field-Effect Transistor** 9
R. Gaska, M.S. Shur, J.W. Yang, and T.A. Fjeldly

**Temperature Dependence of Breakdown Field
in p-π-n GaN Diodes** 15
A. Osinsky, M.S. Shur, and R. Gaska

Low Frequency Noise in n-Type Gallium Nitride 21
*N. Dyakonova, M. Levinshtein, S. Contreras, W. Knap,
B. Beaumont, and P. Gibart*

**Nitride-Based High-Power Devices: Transport Properties,
Linear Defects, and Goals** 27
*Z.Z. Bandić, P.M. Bridger, E.C. Piquette, R.A. Beach, V.M. Phanse,
R.P. Vaudo, J. Redwing, and T.C. McGill*

PART II: CRYSTAL GROWTH

***Growth of AlN Single Crystals** 35
Glen A. Slack

**A New Approach to Growth of Bulk ZnO Crystals for Wide-
Bandgap Applications** 41
G. Agarwal, J.E. Nause, and D.N. Hill

**GaN Nucleation Mechanism on a Surface Template of
Oxidized AlAs** 47
*Nobuhiko P. Kobayashi, Junko T. Kobayashi, Won-Jin Choi,
and P. Daniel Dapkus*

**MOCVD Growth of GaN on Silicon and
Related Surfaces** 53
J. Han, J.G. Fleming, and D.M. Follstaedt

*Invited Paper

Cambridge University Press
978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter
[More information](#)

Flow Modulation Epitaxial Lateral Overgrowth of Gallium Nitride on Masked 6H-Silicon Carbide and Sapphire Surfaces 59
J.A. Smart, E.M. Chumbes, L.N. Srivatsa, Y.H. Lo, and J.R. Shealy

Two-Step Growth of GaN Quantum Dots With Metalorganic Chemical Vapor Deposition 65
P. Chen, B. Shen, R. Zhang, M. Wang, Y.G. Zhou, Z.Z. Chen, L. Zhang, and Y.D. Zheng

Effect of V/III Ratio on the Properties of GaN Layers Grown by Molecular-Beam Epitaxy Using NH₃ 69
N. Grandjean, M. Leroux, J. Massies, M. Mesrine, and P. Lorenzini

PART III: SiC MATERIALS AND DEVICES

***High-Voltage Silicon Carbide Devices** 77
B. Jayant Baliga

***A Theoretical and Empirical Perspective of SiC Bulk Growth** 89
V.F. Tsvetkov, D.N. Henshall, M.F. Brady, R.C. Glass, and C.H. Carter, Jr.

The Response of High-Voltage 4H-SiC *p-n* Junction Diodes to Different Edge-Termination Techniques 101
T.N. Oder, C.C. Tin, J.R. Williams, T. Isaacs-Smith, V. Madangarli, and T.S. Sudarshan

Nonmicropipe Dislocations in 4H-SiC Devices: Electrical Properties and Device Technology Implications 107
P.G. Neudeck, W. Huang, M. Dudley, and C. Fazi

The Origin of Nanopipes and Micropipes in Noncubic GaN and SiC 113
P. Pirouz

5.5-kV Bipolar Diodes From High-Quality CVD 4H-SiC 119
K.G. Irvine, R. Singh, M.J. Paisley, J.W. Palmour, O. Kordina, and C.H. Carter, Jr.

High-Temperature Stable Titanium Carbide Ohmic and Schottky Contacts to SiC 125
C-M. Zetterling, M. Östling, L. Norin, and U. Jansson

Silicon Carbide Epitaxial Layers Grown on SiC Wafers With Reduced Micropipe Density 131
S. Rendakova, N. Kuznetsov, N. Savkina, M. Rastegaeva, A. Andreev, M. Minbaeva, A. Morozov, and V. Dmitriev

Cathodoluminescence Deep-Level Spectroscopy of Etched and *In Situ* Annealed 6H-SiC 137
A.P. Young, K. Aptowitz, and L.J. Brillson

*Invited Paper

Cambridge University Press
978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter
[More information](#)

**The Closed-Form Solutions for the Breakdown Voltages of
6H-SiC Reachthrough Diodes** 143
You-Sang Lee, D-S. Byeon, Y-I. Choi, I-Y. Park, and Min-Koo Han

PART IV: CHARACTERIZATION OF WIDE-BANDGAP SEMICONDUCTORS

**Investigation of Microplasma Breakdown in
4H Silicon Carbide** 151
*Uwe Zimmermann, Anders Hallén, Andrey O. Konstantinov,
and Bo Breitholtz*

**Hot Spots in 4H SiC P+N Diodes Studied by the Optical-
Beam-Induced-Current Technique** 157
*M. Frischholz, K. Nordgren, K. Rottner, J. Seidel, A. Schöner,
and M. Bakowski*

**Scandium and Gallium Implantation Doping
of Silicon Carbide** 163
*T. Henkel, Y. Tanaka, N. Kobayashi, I. Koutzarov, H. Okumura,
S. Yoshida, and T. Ohshima*

**Low-Temperature Chemical Vapor Deposition of 3C-SiC
on 6H-SiC - An X-ray Triple-Crystal Diffractometry and
X-ray Topography Study** 169
J. Chaudhuri, K. Ignatiev, J.H. Edgar, Z.Y. Xie, and Y. Gao

**The Estimation and Revision of Barrier Heights in 4H-SiC and
6H-SiC Schottky Diodes** 175
You-Sang Lee, D-Y. Kim, J-K. Oh, M-K. Han, and Y-I. Choi

**Piezoelectric Quantization in GaInN Thin Films and
Multiple-Quantum-Well Structures** 181
*Christian Wetzel, Tetsuya Takeuchi, Hiroshi Amano,
and Isamu Akasaki*

**The Magnitude of the Piezoelectric Effect in InGaN
Quantum Wells** 187
*Plotr Perlín, Christian Kisielowski, Laila Mattos, Noad A. Shapiro,
Joachim Kruger, Jinwei Yang, and Eicke R. Weber*

**Carrier Relaxation and Recombination in InGaN/GaN
Quantum Heterostructures Probed With Time-Resolved
Cathodoluminescence** 193
*Xingang Zhang, D.H. Rich, J.T. Kobayashi, N.P. Kobayashi,
and P.D. Dapkus*

**Study of Stimulated Emission in InGaN/GaN
Multiquantum Wells in the Temperature Range
of 175-575 K** 199
*S. Bidnyk, Y.H. Cho, T.J. Schmidt, J. Krasinski, J.J. Song, S. Keller,
U.K. Mishra, and S.P. DenBaars*

Cambridge University Press
 978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
 Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
 Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
 Frontmatter
[More information](#)

Role of Nanopipes in Degradation of AlGaIn/GaN/GaN Devices Operating at High Voltage	205
<i>Marek Osiriski, Jinhyun Lee, and Daniel L. Barton</i>	
Turn-On Process in High-Voltage 4H-SiC Thyristors	211
<i>N.V. Dyakonova, M.E. Levinshtein, J.W. Palmour, S.L. Rumyantsev, and R. Singh</i>	
Electrical Stabilization of Diamond MIS Interface and MISFETs by Ultrahigh-Vacuum Process	217
<i>Young Yun, Tetsuro Maki, Hiroyuki Tanaka, and Takeshi Kobayashi</i>	
Effect of NO on the Electrical Characteristics of SiO₂ Grown on p-Type 4H SiC	223
<i>H.F. Li, S. Dimitrijevic, H.B. Harrison, D. Sweatman, and P. Tanner</i>	
Nitridation of Substrates With Hydrazine Cyanurate for the Growth of Gallium Nitride	227
<i>T.J. Kropewnicki and P.A. Kohl</i>	
Reaction Processes at the Initial Stage of Diamond Nucleation on the Surface of Si(111)	233
<i>Fangqing Xie, Youcun Chen, Qingzhe Zhang, and Zhangda Lin</i>	
Deep Levels in High Resistivity AlGaIn Films Grown by MOCVD	239
<i>A.Y. Polyakov, N.B. Smirnov, A.V. Govorkov, and J.M. Redwing</i>	
Studies on the Intermetallic Semiconductor RuAl₂	245
<i>V. Ponnambalam and U.V. Varadaraju</i>	
Semiconducting Molybdenum Pyrochlores for High-Temperature Applications	249
<i>V. Ponnambalam and U.V. Varadaraju</i>	
CVD Diamond as Dielectric Material for Capacitor Applications	255
<i>S. Heidger, S. Fries-Carr, J. Weimer, B. Jordan, and R. Wu</i>	
Vacancy-Type Defects in As-Grown and Proton-Irradiated 6H-SiC	261
<i>Werner Puff, Peter Mascher, and Adam G. Balogh</i>	
Optical Characteristics of MOCVD-Grown InGaIn/GaN Multiple Quantum Wells Investigated by Excitation Energy Dependent PL and PLE Spectroscopy	267
<i>Yong-Hoon Cho, J.J. Song, S. Keller, U.K. Mishra, and S.P. DenBaars</i>	
Comparative Study of GaN MOVPE Growth Processes Using Two Different "Surface Preparation-Carrier Gas" Combinations	273
<i>P. Vennegues, S. Haffouz, A. Bouille, M. Leroux, and B. Beaumont</i>	

Cambridge University Press
978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter
[More information](#)

Thermally Stable Schottky Contacts to n-GaN	279
<i>H.S. Venugopalan and S.E. Mohney</i>	
Reactive Ion Etching of Boron Nitride and Gallium Nitride Materials in Cl₂/Ar and BCl₃/Cl₂/Ar Chemistries	285
<i>N. Medelci, A. Tempez, E. Kim, N. Badi, D. Starikov, I. Berichev, and A. Bensaoula</i>	
Calculation of Unstable Mixing Region in Wurtzite InGaN	291
<i>Toru Takayama, Tetsuzo Ueda, Masahiro Ishida, Masaaki Yuri, Kunio Itoh, Takaaki Baba, and James S. Harris, Jr.</i>	
Spatial Characterization of Doped SiC Wafers	297
<i>J.C. Burton, L. Sun, M. Pophristic, J. Li, F.H. Long, Z.C. Feng, and I. Ferguson</i>	
Transient Photoconductivity of GaN Thin Film on Sapphire Substrate	303
<i>Z.Z. Chen, B. Shen, R. Zhang, X.Y. Zhang, K. Yang, H. Chen, P. Chen, L. Zang, Y.G. Zhou, Y.D. Zheng, Z.S. Wu, X.T. Sun, and F. Chen</i>	
Bulk Breakdown in AlGaIn/GaN HFETs	309
<i>G. Gradinaru, N.C. Kao, R. Gaska, J. Yang, Q. Chen, M.A. Khan, and T.S. Sudarshan</i>	
High-Resolution X-ray Diffraction and X-ray Topography Study of GaN on Al₂O₃	315
<i>J. Chaudhuri, M. Hooe Ng, D.D. Koleske, A.E. Wickenden, and R.L. Henry</i>	
Influence of C, N, and O Ion Implantation on Yellow Luminescence	321
<i>R. Zhang, L. Zhang, N. Perkins, and T.F. Kuech</i>	
Incorporation of Er Into GaN by <i>In Situ</i> Doping During Halide Vapor-Phase Epitaxy	327
<i>Rong Zhang and T.F. Kuech</i>	
Phonons and Holes in Magnesium-Doped GaN	333
<i>F. Demangeot, J. Frandon, M.A. Renucci, D. Smirnov, J. Léotin, N. Grandjean, B. Beaumont, M. Kuball, T. Davies, and J.W. Steeds</i>	
Interfacial Diffusion/Reaction and Electrical Properties of Pd Ultrathin Film on SiC at Different Annealing Temperatures	339
<i>W. Lu, D.T. Shi, W.E. Collins, H. Chen, and A. Burger</i>	
Comparison of High Field Characteristics of SiO₂ and AlN Gate Insulators in 6H SiC MOS Capacitors	345
<i>V.P. Madangarli, T.S. Sudarshan, and C.C. Tin</i>	
Correlation Between Oxide Breakdown and Defects in SiC Wafers	351
<i>S. Soloviev, I. Khlebnikov, V. Madangarli, and T.S. Sudarshan</i>	

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter

[More information](#)

Examination of the Silicon - Silicon Carbide Interface by Ultraviolet Photoemission Spectroscopy	357
<i>C. Koitzsch, M. O'Brien, D. Johri, A. Stoltz, and R. Nemanich</i>	
Polarity of GaN	363
<i>Z. Liliental-Weber, M. Benamara, O. Richter, W. Swider, J. Washburn, I. Grzegory, S. Porowski, J.W. Yang, and S. Nakamura</i>	
Investigation of the V⁴⁺-Center in 6H- and 4H-SiC by the Method of Spectral-Hole Burning	369
<i>C. Hecht, R. Kummer, and A. Winnacker</i>	
The Effect of Thermal Annealing of Au Contacts on 6H-SiC and 4H-SiC	375
<i>D.T. Shi, W. Lu, H. Chen, and W.E. Collins</i>	
Site-Selective Photoluminescence Spectroscopy of Er-Implanted Wurtzite GaN Under Various Annealing Conditions	381
<i>S. Kim, S.J. Rhee, X. Li, J.J. Coleman, and S.G. Bishop</i>	
Growth of III-Nitrides by rf-Assisted Molecular-Beam Epitaxy	387
<i>E.C. Piquette, P.M. Bridger, Z.Z. Bandić, and T.C. McGill</i>	
X-ray Photoemission Spectromicroscopy of GaN and AlGaIn	393
<i>G.F. Lorusso, H. Solak, F. Cerrina, J.H. Underwood, P.J. Batson, Y. Kim, Y. Cho, C. Kisielowski, J. Krueger, and E.R. Weber</i>	
High-Pressure Investigation of InGaIn Quantum Wells	399
<i>Piotr Perlin, Valentin Iota, Bernie A. Weinstein, Henryk Teisseyre, Tadeusz Suski, Steve Hersee, Christian Kisielowski, Eicke R. Weber, and Jinwei Yang</i>	
Direct Growth of AlN Thin Layer on (111)Si Substrate by rf-MBE	405
<i>Naoki Ohshima, Hiroo Yonezu, Shinobu Uesugi, Keisuke Gotoh, and Seiji Yamahira</i>	
Optical Anisotropy Studies of Sapphire by Raman Scattering and Spectroscopic Transmission Ellipsometry	411
<i>H. Yao, C.H. Yan, S.P. DenBaars, and J.M. Zavada</i>	
Epitaxial Films of GaAs and GaN on Fianit Substrates	417
<i>A.N. Buzynin, V.V. Osiko, E.E. Lomonova, Yu.N. Buzynin, and A.S. Usikov</i>	
Search for New Semiconductors for High-Temperature Applications: The BaPb_{1-x}Bi_xO₃ System	423
<i>V. Ponnambalam and U.V. Varadaraju</i>	

Cambridge University Press
978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter
[More information](#)

**PART V: PROCESSING CHARACTERIZATION AND PROPERTIES
OF WIDE-BANDGAP MATERIALS**

Phase Separation and Ordering in InGaN Alloys	431
<i>D. Doppalapudi, S.N. Basu, and T.D. Moustakas</i>	
Low-Temperature Homoepitaxial Growth of GaN Using Hyperthermal Molecular Beams	437
<i>A. Michel, E. Chen, D. Thomson, O. Nam, R.F. Davis, and H.H. Lamb</i>	
In Situ Characterization of AlN Films Grown on Silicon by MOCVD	445
<i>A.D. Serra and H.H. Richardson</i>	
Properties of GaN Homoepitaxial Layers Grown on GaN Epitaxial Wafers	451
<i>V. Dmitriev, A. Nikolaev, A. Cherenkov, D. Tsvetkov, S. Stepanov, N. Kuznetsov, I. Nikitina, A. Kovarsky, M. Yagovkina, and V. Davidov</i>	
Interaction of Nitrogen With 6H-SiC Surfaces	457
<i>V. van Elsbergen, M. Rohleder, and W. Mönch</i>	
Ultrahigh Implant Activation Efficiency in GaN Using Novel High Temperature RTP System	463
<i>X.A. Cao, C.R. Abernathy, R.K. Singh, S.J. Pearton, M. Fu, V. Sarvepalli, J.A. Sekhar, J.C. Zolper, D.J. Rieger, J. Han, T.J. Drummond, R.J. Shul, and R.G. Wilson</i>	
High-Energy Implantation of Boron in 4H-SiC	469
<i>Adolf Schöner, Stefan Karlsson, Thomas Schmitt, Anders Hallén, Manfred Frischholz, and Kurt Rottner</i>	
Doping of GaN by Ion Implantation: Does it Work?	475
<i>A. Suvkhanov, J. Hunn, W. Wu, D. Thomson, K. Price, N. Parikh, E. Irene, R.F. Davis, and L. Krasnobaev</i>	
TEM and HREM Study of High-Temperature Aluminum Ion Implantation to 6H-SiC	481
<i>A.A. Suvorova, I.O. Usov, O.I. Lebedev, G. Van Tendeloo, and A.V. Suvorov</i>	
GaN Etching in BCl₃/Cl₂ Plasmas	487
<i>R.J. Shul, C.I.H. Ashby, C.G. Willison, L. Zhang, J. Han, M.M. Bridges, S.J. Pearton, J.W. Lee, and L.F. Lester</i>	
Dry Etching Damage Effect on Ohmic Characteristics of GaN	495
<i>Jin Seok Khim, Taek Kim, Su Hee Chae, Tae Il Kim, Hyon-Soo Kim, and Geun-Young Yeom</i>	

Cambridge University Press
978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter
[More information](#)

Comparison of Novel Chlorine, Bromine, and Iodine Plasma Chemistries for Anisotropic Trench Etching in GaN, InN, and AlN 501
Hyun Cho, T. Maeda, J.D. MacKenzie, S.M. Donovan, C.R. Abernathy, S.J. Pearton, R.J. Shul, J. Han, and F. Ren

Low Bias Dry Etching of SiC and SiCN in ICP NF₃ Discharges 507
J.J. Wang, Hyun Cho, E.S. Lambers, S.J. Pearton, M. Östling, C-M. Zetterling, J.M. Grow, F. Ren, R.J. Shul, and J. Han

Electrochemical Etching in the GaN-Based Technology 513
V.G. Sidorov, A.G. Drizhuk, D.V. Sidorov, W.V. Lundin, B.V. Pushnyl, and A.S. Usikov

EXAFS Studies of Group-III Nitrides 519
N.J. Jeffs, A.V. Blant, T.S. Cheng, C.T. Foxon, C. Bailey, P.G. Harrison, J.F.W. Mosselmans, and A.J. Dent

The Role of the In Source in InN Growth From Molecular Beams 525
S.M. Donovan, B. Gila, J.D. MacKenzie, K.N. Lee, C.R. Abernathy, R.G. Wilson, and G.T. Muhr

Evidence for Oxygen DX Centers in AlGaN 531
M.D. McCluskey, N.M. Johnson, C.G. Van de Walle, D.P. Bour, M. Kneissl, and W. Walukiewicz

Persistent Photoconductivity in AlGaN Films Grown by MOCVD 537
A.Y. Polyakov, N.B. Smirnov, A.V. Govorkov, and J.M. Redwing

Ion-Scattering Studies of Defects in GaN Thin Films on c-Oriented Sapphire 543
B. Holländer, S. Mantl, M. Mayer, C. Kirchner, A. Pelzmann, M. Kamp, S. Christiansen, M. Albrecht, and H.P. Strunk

Polar Optical-Phonon Instability and Intervalley Transfer in Gallium Nitride 549
B.E. Foutz, S.K. O'Leary, M.S. Shur, L.F. Eastman, B.L. Gelmont, and M. Stroscio

A Semi-Analytical Interpretation of Transient Electron Transport in Gallium Nitride, Indium Nitride, and Aluminum Nitride 555
B.E. Foutz, S.K. O'Leary, M.S. Shur, and L.F. Eastman

Author Index 561

Subject Index 565

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter

[More information](#)

PREFACE

Wide-bandgap semiconductors have a long and illustrious history, starting with the first paper on SiC light-emitting diodes published by Round in 1907. However, in the last few years the number of papers on wide-bandgap semiconductors has skyrocketed. Improved material quality, important breakthroughs both in SiC and GaN technologies (most notably the development of 4H-SiC technology and SiC semi-insulating substrates), and the emergence of blue GaN-based lasers, stimulated this progress. Much credit should also go to the funding agencies, which made wide-bandgap semiconductor research a priority. Applications for this emerging technology include high-power, high-temperature, and high-frequency systems.

The symposium attracted a wide range of researchers who presented 128 papers throughout seven different sessions. Papers cover GaN-based and SiC-based devices, issues related to crystal growth, and processing and characterization of wide-bandgap materials. The invited speakers presented an excellent overview of the current state of the art and made projections for future developments. Overall, these proceedings give a fairly complete and up-to-date picture of this important field and include most of the work presented at the conference.

We would like to thank our invited speakers, Doctors Baliga, Eastman, Mishra, Khan, Slack, and Tsvetkov, and session chairs Jamie Freitas, Steve Pearton, Eric Hellman, Pirouz Pirouz, and Randy Shul. We are also grateful to our colleagues, Professor Tor Fjeldly, Dr. Stephen O'Leary, Dr. James Lu, Dr. Benjamin Iniguez, Mr. Brian Foutz, and Mr. Peter Necluidov, for their help in the preparation of this volume, as well as to the many dedicated anonymous reviewers who made this publication possible.

Generous financial support from AIXTRON, Inc., Cree Research, Inc., EMCORE Corporation, and Northrop Grumman Science and Technology Center also contributed to the success of the symposium.

Steven DenBaars
John Palmour
Michael Shur
Michael Spencer

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter

[More information](#)

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

- Volume 481— Phase Transformation and Systems Driven Far From Equilibrium, E. Ma, P. Bellon, M. Atzmon, R. Trivedi, 1998, ISBN: 1-55899-386-X
- Volume 482— Nitride Semiconductors, F.A. Ponce, S.P. DenBaars, B.K. Meyer, S. Nakamura, S. Strite, 1998, ISBN: 1-55899-387-8
- Volume 483— Power Semiconductor Materials and Devices, S.J. Pearton, R.J. Shul, E. Wolfgang, F. Ren, S. Tenconi, 1998, ISBN: 1-55899-388-6
- Volume 484— Infrared Applications of Semiconductors II, S. Sivananthan, M.O. Manasreh, R.H. Miles, D.L. McDaniel, Jr., 1998, ISBN: 1-55899-389-4
- Volume 485— Thin-Film Structures for Photovoltaics, E.D. Jones, R. Noufi, B.L. Sopori, J. Kalejs, 1998, ISBN: 1-55899-390-8
- Volume 486— Materials and Devices for Silicon-Based Optoelectronics, J.E. Cunningham, S. Coffa, A. Polman, R. Soref, 1998, ISBN: 1-55899-391-6
- Volume 487— Semiconductors for Room-Temperature Radiation Detector Applications II, R.B. James, T.E. Schlesinger, P. Siffert, M. Cuzin, M. Squillante, W. Dusi, 1998, ISBN: 1-55899-392-4
- Volume 488— Electrical, Optical, and Magnetic Properties of Organic Solid-State Materials IV, J.R. Reynolds, A.K-Y. Jen, L.R. Dalton, M.F. Rubner, L.Y. Chiang, 1998, ISBN: 1-55899-393-2
- Volume 489— Materials Science of the Cell, B. Mulder, V. Vogel, C. Schmidt, 1998, ISBN: 1-55899-394-0
- Volume 490— Semiconductor Process and Device Performance Modeling, J.S. Nelson, C.D. Wilson, S.T. Dunham, 1998, ISBN: 1-55899-395-9
- Volume 491— Tight-Binding Approach to Computational Materials Science, P.E.A. Turchi, A. Gonis, L. Colombo, 1998, ISBN: 1-55899-396-7
- Volume 492— Microscopic Simulation of Interfacial Phenomena in Solids and Liquids, S.R. Phillpot, P.D. Bristowe, D.G. Stroud, J.R. Smith, 1998, ISBN: 1-55899-397-5
- Volume 493— Ferroelectric Thin Films VI, R.E. Treece, R.E. Jones, S.B. Desu, C.M. Foster, I.K. Yoo, 1998, ISBN: 1-55899-398-3
- Volume 494— Science and Technology of Magnetic Oxides, M. Hundley, J. Nickel, R. Ramesh, Y. Tokura, 1998, ISBN: 1-55899-399-1
- Volume 495— Chemical Aspects of Electronic Ceramics Processing, P.N. Kumta, A.F. Hepp, D.B. Beach, J.J. Sullivan, B. Arkles, 1998, ISBN: 1-55899-400-9
- Volume 496— Materials for Electrochemical Energy Storage and Conversion II—Batteries, Capacitors and Fuel Cells, D.S. Ginley, D.H. Doughty, T. Takamura, Z. Zhang, B. Scrosati, 1998, ISBN: 1-55899-401-7
- Volume 497— Recent Advances in Catalytic Materials, N.M. Rodriguez, S.L. Soled, J. Hrbeck, 1998, ISBN: 1-55899-402-5
- Volume 498— Covalently Bonded Disordered Thin-Film Materials, M.P. Siegal, J.E. Jaskie, W. Milne, D. McKenzie, 1998, ISBN: 1-55899-403-3
- Volume 499— High-Pressure Materials Research, R.M. Wentzocovitch, R.J. Hemley, W.J. Nellis, P.Y. Yu, 1998, ISBN: 1-55899-404-1
- Volume 500— Electrically Based Microstructural Characterization II, R.A. Gerhardt, M.A. Alim, S.R. Taylor, 1998, ISBN: 1-55899-405-X
- Volume 501— Surface-Controlled Nanoscale Materials for High-Added-Value Applications, K.E. Gonsalves, M-I. Baraton, J.X. Chen, J.A. Akkara, 1998, ISBN: 1-55899-406-8
- Volume 502— *In Situ* Process Diagnostics and Intelligent Materials Processing, P.A. Rosenthal, W.M. Duncan, J.A. Woollam, 1998, ISBN: 1-55899-407-6
- Volume 503— Nondestructive Characterization of Materials in Aging Systems, R.L. Crane, S.P. Shah, R. Gilmore, J.D. Achenbach, P.T. Khuri-Yakub, T.E. Matikas, 1998, ISBN: 1-55899-408-4
- Volume 504— Atomistic Mechanisms in Beam Synthesis and Irradiation of Materials, J.C. Barbour, S. Roorda, D. Ila, 1998, ISBN: 1-55899-409-2
- Volume 505— Thin-Films—Stresses and Mechanical Properties VII, R.C. Cammarata, E.P. Busso, M. Nastasi, W.C. Oliver, 1998, ISBN: 1-55899-410-6
- Volume 506— Scientific Basis for Nuclear Waste Management XX, I.G. McKinley, C. McCombie, 1998, ISBN: 1-55899-411-4
- Volume 507— Amorphous and Microcrystalline Silicon Technology—1998, S. Wagner, M. Hack, H.M. Branz, R. Schropp, I. Shimizu, 1998, ISBN: 1-55899-413-0

Cambridge University Press

978-1-107-41364-1 - Materials Research Society Symposium Proceedings: Volume 512:
Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature
Editors: Steven DenBaars, John Palmour, Michael Shur and Michael Spencer
Frontmatter

[More information](#)

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

- Volume 508— Flat-Panel Display Materials—1998, G. Parsons, T.S. Fahlen, S. Morozumi, C. Seager, C.-C. Tsai, 1998, ISBN: 1-55899-414-9
- Volume 509— Materials Issues in Vacuum Microelectronics, W. Zhu, L.S. Pan, T.E. Felter, C. Holland, 1998, ISBN: 1-55899-415-7
- Volume 510— Defect and Impurity Engineered Semiconductors and Devices II, S. Ashok, J. Chevallier, K. Sumino, B.L. Soporì, W. Goetz, 1998, ISBN: 1-55899-416-5
- Volume 511— Low-Dielectric Constant Materials IV, C. Chiang, J.T. Wetzel, T.-M. Lu, P.S. Ho, 1998, ISBN: 1-55899-417-3
- Volume 512— Wide-Bandgap Semiconductors for High Power, High Frequency and High Temperature, S. DenBaars, M.S. Shur, J. Palmour, M. Spencer, 1998, ISBN: 1-55899-418-1
- Volume 513— Hydrogen in Semiconductors and Metals, N.H. Nickel, W.B. Jackson, R.C. Bowman, 1998, ISBN: 1-55899-419-X
- Volume 514— Advanced Interconnects and Contact Materials and Processes for Future Integrated Circuits, S.P. Murarka, D.B. Fraser, M. Eizenberg, R. Tung, R. Madar, 1998, ISBN: 1-55899-420-3
- Volume 515— Electronic Packaging Materials Science X, D.J. Belton, R. Pearson, M. Gaynes, E.G. Jacobs, 1998, ISBN: 1-55899-421-1
- Volume 516— Materials Reliability in Microelectronics VIII, T. Marieb, J. Bravman, M.A. Korhonen, J.R. Lloyd, 1998, ISBN: 1-55899-422-X
- Volume 517— High-Density Magnetic Recording and Integrated Magneto-Optics: Materials and Devices, K. Rubin, J.A. Bain, T. Nolan, D. Bogy, B.J.H. Stadler, M. Levy, J.P. Lorenzo, M. Mansuripur, Y. Okamura, R. Wolfe, 1998, ISBN: 1-55899-423-8
- Volume 518— Microelectromechanical Structures for Materials Research, S.B. Brown, C. Muhstein, P. Krulevitch, G.C. Johnston, R.T. Howe, J.R. Gilbert, 1998, ISBN: 1-55899-424-6
- Volume 519— Organic/Inorganic Hybrid Materials, R.M. Laine, C. Sanchez, E. Giannelis, C.J. Brinker, 1998, ISBN: 1-55899-425-4
- Volume 520— Nanostructured Powders and Their Industrial Application, G. Beaucage, J.E. Mark, G. Burns, H. Duen-Wu, 1998, ISBN: 1-55899-426-2
- Volume 521— Porous and Cellular Materials for Structural Applications, D.S. Schwartz, D.S. Shih, H.N.G. Wadley, A.G. Evans, 1998, ISBN: 1-55899-427-0
- Volume 522— Fundamentals of Nanoindentation and Nanotribology, N.R. Moody, W.W. Gerberich, S.P. Baker, N. Burnham, 1998, ISBN: 1-55899-428-9
- Volume 523— Electron Microscopy of Semiconducting Materials and ULSI Devices, C. Hayzelden, F.M. Ross, C.J.D. Hetherington, 1998, ISBN: 1-55899-429-7
- Volume 524— Application of Synchrotron Radiation Techniques to Materials Science IV, S.M. Mini, D.L. Perry, S.R. Stock, L.J. Terminello, ISBN: 1-55899-430-0
- Volume 525— Rapid Thermal and Integrated Processing VII, M.C. Öztürk, F. Roozeboom, P.J. Timans, S.H. Pas, 1998, ISBN: 1-55899-431-9
- Volume 526— Advances in Laser Ablation of Materials, R.K. Singh, D.H. Lowndes, D.B. Chrisey, J. Narayan, T. Kawai, E. Fogarassy, 1998, ISBN: 1-55899-432-7
- Volume 527— Diffusion Mechanisms in Crystalline Materials, Y. Mishin, N.E.B. Cowern, C.R.A. Catlow, D. Farkas, G. Vogl, 1998, ISBN: 1-55899-433-5
- Volume 528— Mechanisms and Principles of Epitaxial Growth in Metallic Systems, L.T. Wille, C.P. Burmester, K. Terakura, G. Comsa, E.D. Williams, 1998, ISBN: 1-55899-434-3
- Volume 529— Computational and Mathematical Models of Microstructural Evolution, J.W. Bullard, R. Kalia, M. Stoneham, L.-Q. Chen, 1998, ISBN: 1-55899-435-1
- Volume 530— Biomaterials Regulating Cell Function and Tissue Development, D. Mooney, A.G. Mikos, K.E. Healy, Y. Ikada, R.C. Thomson, 1998, ISBN: 1-55899-436-X
- Volume 531— Reliability of Photonics Materials and Structures, E. Suhir, M. Fukuda, C.R. Kurkjian, 1998, ISBN: 1-55899-437-8
- Volume 532— Silicon Front-End Technology—Materials Processing and Modelling, N.E.B. Cowern, D. Jacobson, P. Griffin, P. Packan, R. Webb, 1998, ISBN: 1-55899-438-6
- Volume 533— Epitaxy and Applications of Si-Based Heterostructures, E.A. Fitzgerald, P.M. Mooney, D.C. Houghton, 1998, ISBN: 1-55899-439-4

Prior Materials Research Society Symposium Proceedings available by contacting Materials Research Society