

---

# **SiGe, Ge, and Related Compounds: Materials, Processing, and Devices 8**

---

**Editors:**

<b>Q. Liu</b>	<b>A. Schulze</b>
<b>J.-M. Hartmann</b>	<b>G. Masini</b>
<b>A. Thean</b>	<b>A. Mai</b>
<b>S. Miyazaki</b>	<b>M. Östling</b>
<b>A. Ogura</b>	<b>G. Niu</b>
<b>X. Gong</b>	<b>D. Harame</b>
<b>M. Caymax</b>	

**Sponsoring Division:****Electronics and Photonics**Published by  
**The Electrochemical Society**65 South Main Street, Building D  
Pennington, NJ 08534-2839, USA

tel 609 737 1902

fax 609 737 2743

[www.electrochem.org](http://www.electrochem.org)**ecstransactions**™**Vol. 86, No. 7**

---

Copyright 2018 by The Electrochemical Society.  
All rights reserved.

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

Published by:

The Electrochemical Society  
65 South Main Street  
Pennington, New Jersey 08534-2839, USA

Telephone 609.737.1902  
Fax 609.737.2743  
e-mail: [ecs@electrochem.org](mailto:ecs@electrochem.org)  
Web: [www.electrochem.org](http://www.electrochem.org)

ISSN 1938-6737 (online)  
ISSN 1938-5862 (print)  
ISSN 2151-2051 (cd-rom)

ISBN 978-1-62332-539-8 (CD-ROM)  
ISBN 978-1-62332-540-4 (USB)  
ISBN 978-1-60768-853-2 (PDF)

---

Printed in the United States of America.

---

**ECS Transactions, Volume 86, Issue 7**  
SiGe, Ge, and Related Compounds: Materials, Processing, and Devices 8

**Table of Contents**

Preface *iii*

**Chapter 1  
Optoelectronics**

Silicon-Germanium Stressors for Germanium Photonic Devices on Silicon *3*  
*M. Nishimura, K. Kawashita, Y. Ishikawa*

(Invited) Heterogeneous Integration of III-V Semiconductors on Si Photonics Platform *11*  
*T. Hiraki, T. Aihara, K. Hasebe, T. Fujii, K. Takeda, H. Nishi, T. Kakitsuka,  
H. Fukuda, T. Tsuchizawa, S. Matsuo*

(Invited) High-Performance Si Optical Modulator and Ge Photodetector and Their Application to Silicon Photonics Integrated Circuit *17*  
*J. Fujikata, S. Takahashi, T. Mogami, K. Kurata, M. Takenaka, T. Nakamura*

**Chapter 2  
FET**

Composition and Strain Evolution of Undoped  $\text{Si}_{0.8}\text{Ge}_{0.2}$  Layers Submitted to UV-Nanosecond Laser Annealing *29*  
*L. Dagault, P. Acosta-Alba, S. Kerdilès, J. P. Barnes, J. M. Hartmann, P. Gergaud,  
T. T. Nguyen, A. Grenier, J. Aubin, F. Cristiano*

(Invited) The Scaling-Down and Performance Optimization of InAs Nanowire Field Effect Transistors *41*  
*Q. Chen, W. Yang*

(Invited) Advanced Replacement High-K/Metal Gate Stack Engineering for High-Performance Strained Silicon-Germanium FinFETs with High Ge Content *51*  
*P. Hashemi, T. Ando, E. A. Cartier, J. Bruley, C. H. Lee, V. Narayanan*

Strain Evaluation of Laser-Annealed SiGe Thin Layers <i>S. Komago, T. Murakami, K. Yoshioka, R. Yokogawa, J. O. Borland, T. Kuroi, T. Tabata, K. Huet, N. Horiguchi, A. Ogura</i>	59
Investigation of Tm <sub>2</sub> O <sub>3</sub> As a Gate Dielectric for Ge MOS Devices <i>L. Žurauskaitė, L. Jones, V. R. Dhanak, I. Z. Mitrovic, P. E. Hellström, M. Östling</i>	67
(Invited) Ultrathin-Body Ge-on-Insulator MOSFET and TFET Technologies <i>S. Takagi, W. K. Kim, K. W. Jo, R. Matsumura, R. Takaguchi, T. Katoh, T. E. Bae, K. Kato, M. Takenaka</i>	75
Evaluation of Laterally Graded Silicon Germanium Wires for Thermoelectric Devices Fabricated by Rapid Melting Growth <i>R. Yokogawa, S. Hashimoto, K. Takahashi, S. Oba, M. Tomita, M. Kurosawa, T. Watanabe, A. Ogura</i>	87

### **Chapter 3 Emerging Applications**

(Invited) Ion Trap Quantum Computing: A New Computing Regime <i>M. Mukherjee, T. Dutta, N. V. Horne, Y. Lei, P. Liu, J. Phua, D. Yum</i>	97
(Invited) The New Silicon Industry: Silicon CMOS ASICs Incorporating Compound Semiconductors <i>E. A. Fitzgerald</i>	109

### **Chapter 4 Poster Session**

Selective Area Growth of InGaAs/InP Quantum Well Nanowires on SOI Substrate <i>Y. Li, M. Wang, X. Fang, Y. M. He, P. Wang, H. Wang, Z. Li, X. Zhou, H. Yu, W. Chen, J. Pan</i>	115
Improving the Performance of the Optical Antenna for Integrated LIDAR with Optical Phased Arrays through High Contrast Grating Structure on SOI Substrate <i>P. Wang, Z. Li, H. Yu, Y. Li, Q. Tang, W. Zhao, X. Zhou, W. Chen, Y. Zhang, J. Pan</i>	123

High Density Formation and Magnetoelectronic Transport Properties of Fe <sub>3</sub> Si Nanodots <i>H. Zhang, K. Makihara, M. Ikeda, A. Ohta, S. Miyazaki</i>	131
Reliability of Silicon Avalanche Photodetector in Geiger Mode <i>Y. Zuo, T. Liu, L. Zhou, J. Zheng, C. Li, Q. L. Liu, B. Cheng, Q. Wang</i>	139

## **Chapter 5 HBT**

(Invited) Physics and Compact Modeling of SiGe HBT Linearity Using Mextram <i>G. Niu, H. Zhang, Y. Li, X. Ding, M. Willemse, A. Scholten</i>	145
Improved Modeling of High Injection Substrate Current in High Voltage Bipolar Transistors <i>Y. Li, G. Niu, W. Chen</i>	155

## **Chapter 6 Epitaxy**

(Invited) Very Low Temperature Epitaxy of Group-IV Semiconductors for Use in FinFET, Stacked Nanowires and Monolithic 3D Integration <i>C. Porret, A. Y. Hikavyy, J. F. Gomez Granados, S. Baudot, A. Vohra, B. Kunert, B. Douhard, J. Bogdanowicz, M. Schaekers, D. Kohen, J. Margetis, J. Tolle, L. Lima, A. Sammak, G. Scappucci, E. Rosseel, R. Langer, R. Loo</i>	163
Benchmark of Disilane and Liquid Si for the Low Temperature Epitaxial Growth of Si, SiGe and SiGeB <i>V. Mazzocchi, J. M. Hartmann, M. Veillerot, J. B. Pin, M. Bauer</i>	177
(Invited) Epitaxy of Direct Bandgap Group IV Si-Ge-Sn Alloys towards Heterostructure Light Emitters <i>N. von den Driesch, D. Stange, D. Rainko, I. Povstugar, U. Breuer, Z. Ikonic, J. M. Hartmann, M. A. Schubert, G. Capellini, H. Sigg, S. Mantl, D. Grützmacher, D. Buca</i>	189

Advantages of Faceted P-Raised Source/Drain in Fully Depleted Silicon on Insulator Technology <i>Ö. I. Aydin, J. R. Holt, C. Le Royer, L. Vanamurthy, T. Feudel, T. Heyne, R. Gerber, M. Lenski, S. Jansen, D. Utess, C. Klein, A. Peeva, G. R. Mulfinger, T. J. McArdle, D. Barge, A. Divay, S. Lehmann, E. Smith, C. Peters, J. U. Sachse</i>	199
Investigation of the Growth of Si-Ge-Sn Pseudomorphic Layers on 200 mm Ge Virtual Substrates: Impact of Growth Pressure, HCl and Si <sub>2</sub> H <sub>6</sub> Flows <i>R. Khazaka, J. Aubin, E. Nolot, J. M. Hartmann</i>	207
A Benchmark of 300mm RP-CVD Chambers for the Low Temperature Epitaxy of Si and SiGe <i>J. M. Hartmann, V. Mazzocchi, F. Pierre, J. P. Barnes</i>	219
(Invited) Epitaxy of GaN on Si (111) for Power Electronics, RF and LEDs <i>M. Charles, J. Kanyandekwe, S. Bos, Y. Baines, E. Morvan, A. Torres, F. Templier, M. Plissonnier</i>	233
Nano-Heteroepitaxy: An Investigation of SiGe Nano-Pillars Coalescence <i>M. Mastari, M. Charles, Y. Bogumilowicz, P. Pimenta-Barros, M. Argoud, R. Tiron, A. M. Papon, D. Muyard, N. Chevalier, D. Landru, Y. Kim, J. M. Hartmann</i>	249
Self-Ordered Ge Nanodot Fabrication by Reduced Pressure Chemical Vapor Deposition <i>Y. Yamamoto, Y. Itoh, P. Zaumseil, M. A. Schubert, G. Capellini, K. Washio, B. Tillack</i>	259

## Chapter 7

### Surfaces and Interfaces

(Invited) Large-Scale DFT Study of Ge/Si 3D Nanoislands and Core-Shell Nanowires <i>T. Miyazaki</i>	269
(Invited) HfO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> Nanolaminate on Si <sub>0.7</sub> Ge <sub>0.3</sub> (100) Surface by Thermal Atomic Layer Deposition <i>I. Kwak, K. Sardashti, M. S. Clemons, S. T. Ueda, B. Fruhberger, S. Oktyabrsky, A. C. Kummel</i>	281
Physics of Fermi-Level “Unpinning” at Metal/Ge Interfaces; First-Principles View <i>T. Nakayama, T. Nishimoto</i>	291

Comparative Analysis of Ni- and Ni <sub>0.9</sub> Pt <sub>0.1</sub> -Ge <sub>0.9</sub> Sn <sub>0.1</sub> Solid-State Reaction by Combined Characterizations Methods	299
---	-----

*A. Quintero, P. Gergaud, J. Aubin, J. M. Hartmann, N. Chevalier, V. Reboud,  
E. Cassan, P. Rodriguez*

## Chapter 8 Strain Engineering

(Invited) Raman Stress Measurements at the Nanoscale	311
--	-----

*T. Nuyttten, J. Bogdanowicz, I. Aslam, L. Witters, G. Eneman, T. Hantschel,  
A. Schulze, P. Favia, H. Bender, I. De Wolf, W. Vandervorst, P. van der Heide*

(Invited) A New Application of Ge <sub>1-x</sub> Sn <sub>x</sub> : Thermoelectric Materials	321
---	-----

*M. Kurosawa, Y. Imai, T. Iwahashi, K. Takahashi, M. Sakashita, O. Nakatsuka,  
S. Zaima*

Evaluation of Anisotropic Three-Dimensional Strain Relaxation in Stripe-Shaped Ge <sub>1-x</sub> Sn <sub>x</sub> Mesa Structure	329
---	-----

*Y. Takahashi, R. Yokogawa, T. Murakami, I. Hirosawa, K. Suda, A. Ogura*

Evaluating the Relationship between Phonon and Thermal Properties of Group IV Alloys Using Molecular Dynamics Simulation	337
--	-----

*M. Tomita, M. Ogasawara, T. Terada, T. Watanabe*

## Chapter 9 Processing

The Growth of GeSn Layer on Patterned Si Substrate by MBE Method	349
--	-----

*K. Yu, Y. Zhao, C. Li, S. Feng, X. Chen, Y. Wang, Y. Zuo, B. Cheng*

Boosting Ge-Epi P-Well Mobility & Crystal Quality with Si or Sn Implantation and Melt Annealing	357
---	-----

*J. O. Borland, S. S. Chaung, T. Y. Tseng, A. Joshi, B. Basol, Y. J. Lee, T. Kuroi,  
T. Tabata, K. Huet, G. Goodman, N. Khapochkina, T. Buyuklimanli*

(Invited) Si <sub>1-x</sub> Ge <sub>x</sub> /Si MQW Based Uncooled Microbolometer Development and Integration into 130 nm BiCMOS Technology	373
---	-----

*C. Baristiran Kaynak, Y. Yamamoto, A. Göritz, F. Korndoerfer, P. Zaumseil,  
P. Kulse, K. Schulz, M. Fraschke, S. Marschmeyer, D. Wolansky, M. Wietstruck,  
A. Shafiq, Y. Gurbuz, M. Kaynak*

## **Chapter 10 Metrology**

Ascertaining the Nature and Distribution of Extended Crystalline Defects in Emerging Semiconductor Materials Using Electron Channeling Contrast Imaging	387
<i>A. Schulze, H. Han, L. Strakos, T. Vystavel, C. Porret, R. Loo, M. Caymax</i>	

(Invited) Determining Si Composition in SiGe Alloys with < 1% Si Concentrations Using Raman Spectroscopy	397
<i>I. De Wolf, V. Simons, S. A. Srinivasan, P. Verheyen, R. Loo</i>	

## **Chapter 11 Joint Session: Strain & Metrology & Characterization**

(Invited) High-Sn Concentration MOCVD-Grown Strained GeSn Thin Films Evaluated Using HAXPES and XRD Base on Synchrotron Technique	411
<i>K. Usuda, M. Yoshiki, K. Suda, A. Ogura, M. Tomita</i>	

Determination of Phonon Deformation Potentials in Carbon-Doped Silicon	419
<i>K. Yoshioka, R. Yokogawa, T. Murakami, S. Komago, N. Sawamoto, A. Ogura</i>	

An Interpretation for Defect-Induced Structural Transformation in SiC	427
<i>T. Ito, T. Akiyama, K. Nakamura, A. M. Pradipio</i>	

Author Index	433
--------------	-----