
Physics and Technology of High-k Gate Dielectrics 7

Editors:

S. Kar

Indian Institute of Technology
Kanpur, India

M. Houssa

University of Leuven
Leuven, Belgium

S. Van Elshocht

IMEC
Leuven, Belgium

D. Landheer

Institute for Microstructural Sciences, National Research Council
Ottawa, Ontario, Canada

Sponsoring Divisions:



Dielectric Science & Technology



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

ecstransactions™

Vol. 25 No. 6

Copyright 2009 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
Web: www.electrochem.org

ISSN 1938-6737 (online)
ISSN 1938-5862 (print)

ISBN 978-1-56677-743-8 (Hardcover)
ISBN 978-1-60768-093-2 (PDF)

Printed in the United States of America.

Table of Contents

Preface *iii*

Chapter 1 **Work Function/Flat-Band Voltage Control**

Anomalous V_{FB} Shift in High-k Gate Stacks - Is its Origin at the Top or Bottom Interface ? - *	3
<i>A. Toriumi and T. Nabatame</i>	
Impact of Alkali Earth Elements Incorporation on Electrical Characteristics of La_2O_3 Gated MOS Device	17
<i>T. Koyanagi, K. Okamoto, K. Kakushima, P. Ahmet, K. Tsutsui, A. Nishiyama, N. Sugii, K. Natori, T. Hattori and H. Iwai</i>	
Flat-band Voltage and Structural Properties of Hafnium Dioxide Films Grown by Liquid-injection MOCVD	23
<i>F. Ducroquet, E. Rauwel and C. Dubourdieu</i>	
Work Function Control on High K Metal Gate Stacks *	33
<i>J. Robertson</i>	

Chapter 2 **Ge/III-V Channel Materials - I**

High-k Dielectrics and Interface Passivation for Ge and III/V Devices on Silicon for Advanced CMOS *	51
<i>M. M. Heyns, F. Bellenger, G. Brammertz, M. Caymax, B. De Jaeger, A. Delabie, G. Eneman, M. Houssa, D. Lin, K. Martens, C. Merckling, M. Meuris, J. Mitard, J. Pénard, G. Pourtois, M. Scarrozza, E. Simoen, S. Sioncke, S. Van Elshocht and W. Wang</i>	
Electrical Properties of Lanthanum-scandate Gate Dielectric Directly Deposited on Ge	67
<i>M. K. Bera, J. Song, K. Kakushima, P. Ahmet, K. Tsutsui, N. Sugii, T. Hattori and H. Iwai</i>	

Effects of the Semiconductor Substrate Material on the Post-breakdown Current of MgO Dielectric Layers	79
<i>E. Miranda, E. O'Connor, G. Hughs, P. Casey, K. Cherkaoui, S. Monaghan, R. Long, D. O'Connell and P. Hurley</i>	

InAs-Channel Metal-Oxide-Semiconductor HEMTs with Atomic-Layer-Deposited Al ₂ O ₃ Gate Dielectric	87
<i>C. Chang, E. Chang, W. Huang, Y. Su, H. Trinh, H. Hsu and Y. Miyamoto</i>	

Chapter 3 Ge/III-V Channel Materials - II

Barrier Characterization at Interfaces of High-Mobility Semiconductors with Oxide Insulators *	95
<i>V. V. Afanas'ev and A. Stesmans</i>	

Defects Generation under Constant Voltage Stress in La ₂ O ₃ /HfO ₂ Gate Stacks Grown on Ge Substrates	105
<i>E. K. Evangelou, M. S. Rahman, A. Dimoulas and S. Galata</i>	

Structural and Electrical Properties of HfO ₂ /n-In _x Ga _{1-x} As structures (x: 0, 0.15, 0.3 and 0.53) *	113
<i>P. K. Hurley, E. O'Connor, S. Monaghan, R. Long, A. O'Mahony, I. M. Povey, K. Cherkaoui, J. MacHale, A. Quinn, G. Brammertz, M. M. Heyns, S. Newcomb, V. V. Afanas'ev, A. Sonnet, R. Galatage, N. Jivani, E. Vogel, R. M. Wallace and M. Pemble</i>	

Chapter 4 High-k Materials: Processing & Characterization - I

Modeling of Alternative High-k Dielectrics for Memory Based Applications *	131
<i>G. Pourtois, S. Clima, K. Sankaran, P. Delugas, V. Fiorentini, W. Magnus, B. Soree, S. Van Elshocht, C. Adelman, J. Van Houdt, D. Wouters, S. De Gendt, M. M. Heyns and J. Kittl</i>	

Dielectric Properties of Thin Hf- and Zr-based Alkaline Earth Perovskite Layers	147
<i>G. Lupina, P. Dudek, G. Kozłowski, J. Dąbrowski, G. Lippert, H. Müssig and T. Schroeder</i>	

Stable HfO ₂ based Layers Fabricated by RF Magnetron Sputtering	153
<i>L. Khomenkova, C. Dufour, P. Coulon, C. Bonafos and F. Gourbilleau</i>	

Structure of Hafnium Silicate Films Formed by Atomic Layer Deposition <i>J. Liu, X. Wu, W. Lennard and D. Landheer</i>	163
Formation and Characterization of Thin Silicon Dioxide Films Obtained by Inductively-Coupled High-Density Plasmas using a Dual Rotated Spiral Antenna System <i>Y. Kim, S. Woo, H. Kim, P. Um, J. Ji and C. Kim</i>	173
Nitrogen Incorporation in Al ₂ O ₃ Thin Films Prepared by Pulsed Ultrasonic Sprayed Pyrolysis <i>S. Carmona-Tellez, C. Palacio, S. Gallardo, Z. Rivera, J. Guzman-Mendoza, M. Aguilar-Frutis, M. Garcia-Hipolito, G. Alarcon-Flores and C. Falcony</i>	179
Electron Beam Induced Orientation Selective Epitaxial Growth of CeO ₂ (100)/Si(100) Structures using Absorption Electron Imaging System <i>T. Inoue and S. Shida</i>	187

Chapter 5 DRAM

High Density MIM Capacitors Using HfAlO _x <i>M. K. Hota, C. Mahata, C. K. Sarkar and C. Maiti</i>	201
Physical and Electrical Characterization of Fluorine Plasma Treated Hafnium Oxide Film for High Density Metal-Insulator-Metal Capacitors <i>S. Ding, Y. Huang, Q. Sun and W. Zhang</i>	209
Group-II Hafnate, Zirconate, and Tantalate High-k Dielectrics for MIM Applications: The Defect Issue * <i>J. Dąbrowski, P. Dudek, G. Kozłowski, G. Lupina, G. Lippert, R. Schmidt, C. Walczyk and C. Wenger</i>	219
Impact of Voltage and Current Stress on TiN/HfSi _x O _y /TiN MIM Capacitors <i>K. Jyothis, A. Chandorkar and D. Misra</i>	241

Chapter 6 Ge/III-V Channel Materials - III

Progress Towards Passivation of High-Mobility Channels * <i>M. Houssa, V. V. Afanas'ev, A. Stesmans, M. Meuris and M. M. Heyns</i>	249
---	-----

Electrical Characteristics of HfO ₂ and La ₂ O ₃ Gate Dielectrics for In _{0.53} Ga _{0.47} As MOS Structure	265
<i>K. Funamizu, Y. Lin, K. Kakushima, P. Ahmet, K. Tsutsui, N. Sugii, E. Chang, T. Hattori and H. Iwai</i>	
Small Signal Response of Inversion Layers in High Mobility In _{0.53} Ga _{0.47} As MOSFETs Made with Thin High-k Dielectrics *	271
<i>A. Ali, H. Madan, S. Koveshnikov and S. Datta</i>	
High-k Dielectrics for Ge, III-V and Graphene MOSFETs *	285
<i>S. K. Banerjee, E. Tutuc, S. Kim, T. Akyol, M. Jamil, D. Shahredji, J. Donnelly and L. Colombo</i>	
Low Temperature Fabrication of AlN/Ge Structure Using Electron Cyclotron Resonance Plasma Nitridation	301
<i>J. Kishiwada, N. Mohamed, Y. Oniki, Y. Iwasaki and T. Ueno</i>	

Chapter 7 Interfaces

Interface Engineering of a Metal/ High-k/ Semiconductor Layered Structure by Water Vapor Discharge *	309
<i>K. Muraoka</i>	
Annealing-temperature Dependence of Compositional Depth Profiles and Chemical Bonding States of CeO _x /LaO _x /Si and LaO _x /CeO _x /Si Structure	321
<i>H. Nohira, Y. Kon, K. Kitamura, M. Kouda, K. Kakushima and H. Iwai</i>	
Comparison of Lateral Non-uniformity Phenomena between HfO ₂ and SiO ₂ from Magnified C-V Curves in Inversion Region	327
<i>J. Cheng, C. Huang, H. Lu and J. Hwu</i>	
Crystallographic Orientation Dependent Electrical Characteristics of La ₂ O ₃ MOS Capacitors	339
<i>H. Nakayama, K. Kakushima, P. Ahmet, E. Ikenaga, K. Tsutsui, N. Sugii, T. Hattori and H. Iwai</i>	

Chapter 8
High-k Materials: Processing & Characterization - II

- Solution-Based Fabrication of High-k Dielectrics Using Oxide Nanosheets 349
M. Osada, K. Akatsuka, Y. Ebina, H. Funakubo, K. Takada and T. Sasaki
- Interface and Bulk Properties of MBE-Grown Rare-Earth Metal Oxides on Silicon 353
Y. V. Gomeniuk, Y. V. Gomeniuk, A. Nazarov, V. Lysenko, H. Osten and A. Laha

Chapter 9
Electrical Characterization & Reliability

- Characterization of Stacked Hafnium Oxide (HfO₂)/Silicon Dioxide (SiO₂) Metal-Oxide-Semiconductor (MOS) Tunneling Temperature Sensors 361
C. Wang and J. Hwu
- Long TDDDB Lifetime of SiO₂ Film by Controlling Degradation Rate and SiO₂/Si Micro-roughness 371
Y. Kabe, J. Kitagawa, Y. Hirota, S. Sato, M. Sometani, R. Hasunuma and K. Yamabe
- DLTS of ALD HfO₂ on s-Si/SiGe/Si: Effects of s-Si Thickness and Surface Nitridation 379
L. Yu, G. George Rozgonyi, P. Shrestha, D. Gu and H. Baumgart
- Effects of the Inductively Coupled Plasma Nitridation Process on the Reliability of HfAlO_x Thin Films 387
K. Chang, B. Chen and M. Su
- Nature of Interface Traps in Si/SiO₂/HfO₂ /TiN Gate Stacks and its Correlation with the Flat-band Voltage Roll-off 399
S. Kar

Chapter 10
Exploratory Applications

- Transition Metal Binary Oxides for ReRAM Applications * 411
S. Spiga, A. Lamperti, E. Cianci, F. G. Volpe and M. Fanciulli

Demonstration of Transconductance Enhancement on (110) and (001) Strained-Nanowire FETs	427
<i>A. Seike, H. Takai, I. Tsuchida, J. Masuda, D. Kosemura, A. Ogura, T. Watanabe and I. Ohdomari</i>	
Electrochemical Reactions in Nanoionics - Towards Future Resistive Switching Memories *	431
<i>R. Waser and I. Valov</i>	
Electron-phonon Scattering Effect on Strained Si Nanowire FETs at Low Temperature	439
<i>I. Tsuchida, A. Seike, H. Takai, J. Masuda, D. Kosemura, A. Ogura, T. Watanabe and I. Ohdomari</i>	
Chapter 11	
Non-Volatile Memory	
Improved Device Characteristics in Charge-Trapping-Engineered Flash Memory Using High-k Dielectrics *	447
<i>A. Chin, S. Lin, C. Tsai and F. Yeh</i>	
Failure Analysis of Single and Dual nc-ITO Embedded ZrHfO High-k Nonvolatile Memories	457
<i>C. Yang, Y. Kuo, C. Lin and W. Kuo</i>	
Nonvolatile Memory Capacitors Based on Double Gold nanocrystals and HfO ₂ Tunneling and HfNO/HfTiO Laminated Control High-k Insulator Layers	465
<i>V. Mikhelashvili, B. Meyler, J. Salzman, J. Salzman, M. Garbrecht, T. Cohen-Hyams, W. Kaplan and G. Eisenstein</i>	
Application of ALD High-k Dielectric Films as Charge Storage Layer and Blocking Oxide in Nonvolatile Memories	473
<i>X. Zhu, D. Gu, Q. Li, H. Baumgart, D. Ioannou, J. Suehle and C. Richter</i>	
Metal/High-k/Metal Nanocrystal/SiO ₂ Gate Stacks for NAND Flash Applications *	481
<i>S. Mahapatra and P. K. Singh</i>	
Author Index	491

* invited paper