

Stress Induced Phenomena and Reliability in 3D Microelectronics

Editors

Paul S. Ho University of Texas, Texas, USA

Kyoto, Japan 28-30 May 2012

Chao-Kun Hu IBM T.J. Watson Research Center, New York, USA

Mark Nakamoto Qualcomm Incorporated, California, USA

Shinichi Ogawa Advanced Industrial Science and Technology, Ibaraki, Japan

Valeriy Sukharev Mentor Graphics Corporation, California, USA

Larry Smith SEMATECH, New York, USA

Ehrenfried Zschech Fraunhofer Institute for Ceramic Technologies and Systems, Dresden, Germany

All papers have been peer reviewed.



Melville, New York, 2014 AIP Proceedings

Volume 1601

Editors

Paul S. Ho

University of Texas at Austin Microelectronics Research Center Mechanical Engineering Department 10100 Burnet Road, Bldg. 160 Austin, Texas 78758 USA

E-mail: hops@austin.utexas.edu

Chao-Kun Hu

IBM T.J. Watson Research Center 1101 Kitchawan Road, Route 134 Yorktown Heights, NY 10598 USA

E-mail: haohu@us.ibm.com

Mark Nakamoto

Qualcomm Inc. 5775 Morehouse Drive, R-106E San Diego, CA 92121-1714 USA

E-mail: nakamoto@qti.gualcomm.com

Shinichi Ogawa

Advanced Industrial Science and Technology (AIST) West 7A, 16-1 Onogawa, Tsukuba Ibaraki, 305-8569 Japan

E-mail: ogawa.shinichi@aist.go.jp

Valeriy Sukharev

Mentor Graphics Corporation 46871 Bayside Parkway Fremont, CA 94538 USA

E-mail: Valeriy_Sukharev@mentor.com

Larry Smith

SEMATECH 3D Interconnect Division 257 Fuller Road, Suite 2200 Albany, NY 12203 USA

E-mail: larry.smith@alum.mit.edu

Ehrenfried Zschech

Fraunhofer Institute for Ceramic Technologies and Systems IKTS Maria-Reiche-Strasse 2 D-01109 Dresden, Germany

E-mail: Ehrenfried.Zschech@ikts-md.fraunhofer.de

Authorization to photocopy items for internal or personal use, beyond the free copying permitted under the 1978 U.S. Copyright Law (see statement below), is granted by the AIP Publishing LLC for users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$30.00 per copy is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923, USA: http://www. copyright.com. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Services is: 978-0-7354-1235-4/14/\$30.00

C 2014 AIP Publishing LLC

No claim is made to original U.S. Government works.

Permission is granted to quote from the AIP Conference Proceedings with the customary acknowledgment of the source. Republication of an article or portions thereof (e.g., extensive excerpts, figures, tables, etc.) in original form or in translation, as well as other types of reuse (e.g., in course packs) require formal permission from AIP Publishing and may be subject to fees. As a courtesy, the author of the original proceedings article should be informed of any request for republication/reuse. Permission may be obtained online using RightsLink. Locate the article online at http://proceedings.aip.org, then simply click on the RightsLink icon/"Permissions/Reprints" link found in the article abstract. You may also address requests to: AIP Publishing Office of Rights and Permissions, Suite 300, 1305 Walt Whitman Road, Melville, NY 11747-4300, USA; Fax: 516-576-2450; Tel.: 516-576-2268; E-mail: rights@aip.org.

ISBN 978-0-7354-1235-4'*Qtki kpcrlRtkpv+ ISSN 0094-243X Printed in the United States of America

AIP Conference Proceedings, Volume 1601 Stress Induced Phenomena and Reliability in 3D Microelectronics

Table of Contents

Preface: Stress-Induced Phenomena and Reliability in 3D Microelectronics Paul S. Ho, Chao-Kun Hu, Mark Nakamoto, Shinichi Ogawa, Larry Smith, Valeriy Sukharev, and Ehrenfried Zschech	1
OVERVIEW ON STRESSES AND RELIABILITY IN 3D STRUCTURES Stress management for 3D through-silicon-via stacking technologies - The next frontier - Riko Radojcic, Matt Nowak, and Mark Nakamoto	3
Multi-scale simulation flow and multi-scale materials characterization for stress management in 3D through-silicon-via integration technologies – Effect of stress on 3D IC interconnect reliability Valeriy Sukharev and Ehrenfried Zschech	18
Characterization of thermal stresses and plasticity in through-silicon via structures for three-dimensional integration Tengfei Jiang, Suk-Kyu Ryu, Jay Im, Rui Huang, and Paul S. Ho	55
Microstructure, impurity and metal cap effects on Cu electromigration CK. Hu, L. G. Gignac, J. Ohm, C. M. Breslin, E. Huang, G. Bonilla, E. Liniger, R. Rosenberg, S. Choi, and A. H. Simon	67
Advanced concepts for TDDB reliability in conjunction with 3D stress Martin Gall, Kong Boon Yeap, and Ehrenfried Zschech	79
ELECTROMIGRATION, STRESS AND RELIABILITY IN 3D STRUCTURES Electromigration void nucleation and growth analysis using large-scale early failure statistics M. Hauschildt, M. Gall, C. Hennesthal, G. Talut, O. Aubel, K. B. Yeap, and E. Zschech	89
Modeling of microstructural effects on electromigration failure H. Ceric, R. L. de Orio, W. Zisser, and S. Selberherr	99
Physics-based simulation of EM and SM in TSV-based 3D IC structures Armen Kteyan, Valeriy Sukharev, and Ehrenfried Zschech	114

TCAD modeling of stress impact on performance and reliability in 3D IC structures Xiaopeng Xu and Aditya Karmarkar	128
Design for reliability of BEoL and 3-D TSV structures – A joint effort of FEA and innovative experimental techniques Jürgen Auersperg, Dietmar Vogel, Ellen Auerswald, Sven Rzepka, and Bernd Michel	138
MULTI-SCALE MATERIALS PARAMETERS, SIMULATION AND CHARACTERIZATION Thermomechanical characterization and modeling for TSV structures Tengfei Jiang, Suk-Kyu Ryu, Qiu Zhao, Jay Im, Paul S. Ho, and Rui Huang	148
Assessment of fracture and elastoplastic properties of thin and very thin films M. Trueba, D. Gonzalez, I. Ocaña, M. R. Elizalde, J. M. Martinez-Esnaola, M. T. Hernandez, M. Haverty, G. Xu, and D. Pantuso	158
3D imaging of semiconductor components by discrete laminography K. J. Batenburg, W. J. Palenstijn, and J. Sijbers	168
Effects of fluoride residue on thermal stability in Cu/porous low-k interconnects Y. Kobayashi, S. Ozaki, and T. Nakamura	180