

PROCEEDINGS OF SPIE

Design-Process-Technology Co-optimization for Manufacturability XII

**Jason P. Cain
Chi-Min Yuan**
Editors

**28 February–1 March 2018
San Jose, California, United States**

Sponsored by
SPIE

Cosponsored by
Hitachi High Technologies, America, Inc. (United States)

Published by
SPIE

Volume 10588

Proceedings of SPIE 0277-786X, V. 10588

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Design-Process-Technology Co-optimization for Manufacturability XII, edited by
Jason P. Cain, Chi-Min Yuan, Proc. of SPIE Vol. 10588, 1058801 © 2018 SPIE
CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2324886

Proc. of SPIE Vol. 10588 1058801-1

The papers in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIDigitalLibrary.org.

The papers reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from these proceedings:

Author(s), "Title of Paper," in *Design-Process-Technology Co-optimization for Manufacturability XII*, edited by Jason P. Cain, Chi-Min Yuan, Proceedings of SPIE Vol. 10588 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X
ISSN: 1996-756X (electronic)

ISBN: 9781510616684
ISBN: 9781510616691 (electronic)

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org

Copyright © 2018, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/18/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

**SPIE. DIGITAL
LIBRARY**

SPIDigitalLibrary.org

Paper Numbering: *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc. The CID Number appears on each page of the manuscript.

Contents

vii	<i>Authors</i>
ix	<i>Conference Committee</i>

SESSION 1 TRENDS IN DPTCO

- 10588 03 **Efficient place and route enablement of 5-tracks standard-cells through EUV compatible N5 ruleset** [10588-2]
- 10588 04 **Patterning method impact on sub-36nm pitch interconnect variability** [10588-3]
- 10588 05 **Applying machine learning to pattern analysis for automated in-design layout optimization** [10588-4]

SESSION 2 PATTERN CORRECTION METHODS: JOINT SESSION WITH CONFERENCES 10588 AND 10587

- 10588 06 **Optimization of optical proximity correction to reduce mask write time using genetic algorithm** [10588-5]
- 10588 07 **Dependencies of bias tables to pattern density, critical dimension, global coordinates and pattern orientation for nanoimprint master manufacturing for the 200 mm wafer scale SmartNIL process** [10588-6]

SESSION 3 DESIGN-TECHNOLOGY CO-OPTIMIZATION

- 10588 08 **Pre-PDK block-level PPAC assessment of technology options for sub-7nm high-performance logic (Invited Paper)** [10588-7]
- 10588 09 **Track height reduction for standard-cell in below 5nm node: how low can you go?** [10588-8]
- 10588 0A **A compact multi-bit flip-flop with smaller height implementation and metal-less intra-cell routing** [10588-9]
- 10588 0B **DTCO exploration for efficient standard cell power rails** [10588-10]

SESSION 4 LAYOUT OPTIMIZATION

- 10588 0C **Post-decomposition optimizations using pattern matching and rule-based clustering for multi-patterning technology** [10588-11]

- 10588 OD **Pin routability and pin access analysis on standard cells for layout optimization** [10588-12]
- 10588 OE **Variability-aware double-patterning layout optimization for analog circuits** [10588-13]
- 10588 OF **Litho friendly via insertion with in-design auto-fix flow using machine learning** [10588-14]

SESSION 5 DESIGN INTERACTIONS: JOINT SESSION WITH CONFERENCES 10585 AND 10588

- 10588 OG **A model-based, Bayesian approach to the CF₄/Ar etch of SiO₂** [10588-15]

SESSION 6 PATTERN-BASED ANALYSIS

- 10588 OI **Hotspot detection based on surrounding optical feature** [10588-18]
- 10588 OJ **Range pattern matching with layer operations and continuous refinements** [10588-19]
- 10588 OK **Combinational optical rule check on hotspot detection**
[10588-20]
- 10588 OL **Pattern analysis and classification accelerates OPC tuning, monitoring, and optimization and mask inspection** [10588-21]

SESSION 7 ADVANCED PATTERNING

- 10588 ON **IMEC N7, N5 and beyond: DTCO, STCO and EUV insertion strategy to maintain affordable scaling trend (Invited Paper)** [10588-22]
- 10588 OO **Relaxing LER requirement in EUV lithography** [10588-23]
- 10588 OP **Comparison between multi-colored LEⁿ SADP/SAQP and selective-etching SADP/SAQP**
[10588-25]
- 10588 OQ **Integrated manufacturing flow for selective-etching SADP/SAQP** [10588-24]

POSTER SESSION

- 10588 OR **Timing optimization in SADP process through wire widening and double via insertion**
[10588-26]
- 10588 OS **Characterization of metal line-width variation in via first dual-damascene approach and its modeling using machine learning artificial neural network algorithms** [10588-27]
- 10588 OT **Cross-MEEF assisted SRAF print avoidance approach** [10588-28]
- 10588 OU **A weak pattern random creation and scoring method for lithography process tuning**
[10588-29]

- 10588 0V **Pattern-based IP block detection, verification, and variability analysis** [10588-30]
- 10588 0W **A smart way to identify and extract repeated patterns of a layout** [10588-31]
- 10588 0X **Using pattern based layout comparison for a quick analysis of design changes** [10588-32]
- 10588 0Y **An efficient way of layout processing based on calibre DRC and pattern matching for defects inspection application** [10588-33]
- 10588 0Z **Leveraging pattern matching to solve SRAM verification challenges at advanced nodes** [10588-34]
- 10588 10 **A portable pattern-based design technology co-optimization flow to reduce optical proximity correction run-time** [10588-35]
- 10588 11 **Hybrid hotspot library building based on optical and geometry analysis at early stage for new node development** [10588-36]

Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Abe, Yayori, 0I
Ahmad Ibrahim, Muhamad Asraf Bin, 0V
Ali, Rehab Kotb, 0P, 0Q
Asthana, Abhishek, 06
Baert, R., 03
Bakshi, Janam, 0F
Batarseh, Fadi, 0F
Baum, Z., 08
Berekovic, M., 03
Blanco, Victor, 0N
Bonnecaze, Roger, 0G
Boudaa, F., 07
Brown, William, 0T
Cain, Jason P., 05, 0F
Cantù, Pietro, 0S
Cao, Liang, 06
Catarisano, Chiara, 0S
Chae, Jung Kyu, 09
Chanemougame, D., 08
Chartoire, J., 07
Chava, Bharani, 0B
Chen, Han, 0W
Chen, James C.-H., 04
Chen, Jian, 0D
Chen, Kao-Tun, 10
Chen, Yi-Chieh, 10
Chen, Ying, 11
Cheng, Jing, 06
Chopra, Meghali, 0G
Chu, Zhihao, 0W
Corneo, Nicoletta, 0S
Debacker, Peter, 03, 09, 0B, 0N
Delachat, F., 07
Deng, Guogui, 0U
Dick, Gregory J., 06
Du, Chunshan, 0U, 0W, 0X, 0Y, 0Z
Dundulachi, Alessandro, 0S
ElManhawly, Wael, 0U
Elsemary, Ahmed Mounir, 0F
Facchini, M., 08
Fakhry, Moutaz, 05, 0F
Fatehy, Ahmed Hamed, 0P, 0Q
Gai, Tianyang, 11
Gao, Gensheng, 0U
Gao, Shaowen, 0K
Gennari, Frank, 05
Gerousis, V., 03, 08, 09
Gillijns, Werner, 0N
Gu, Tingting, 0W
Gupta, Puneet, 0O
Han, G., 08
Helpert, Sofia, 0G
Hu, Xinyi, 0U, 0W, 0X, 0Y, 0Z
Huang, Elven, 0Z
Huang, Lucas, 0X, 0Z
Hurat, Philippe, 0L, 0V, 10
Hyun, Daijoon, 0R
Ismail, Mohamed, 0F
Jung, Jinwook, 0A, 0R
Kabeel, Aliaa, 0U
Kajiwara, Masanari, 0I
Kamal Baharin, Ezni Aznida Binti, 0V
Kan, Huan, 0X, 0Z
Kim, Ryoung-Han, 03, 09, 0N
Kotani, Toshiya, 0I
Kwan, Joe, 0U
Lai, Ya-Chieh, 05, 0D, 0L, 0V, 10
Lee, Jae Uk, 0N
Lee, Robben, 0Y
Lee, Tyzy, 0Y
Lee, Zhao Chuan, 0E, 0J
Li, Helen, 0Y
Li, Shuai, 0D
Li, Tsung-Han, 10
Li, Yongfu, 0E, 0J
LiCausi, Nicholas V., 04
Liebmann, L., 08
Lin, Eason, 0D
Lin, Hung-Yu, 10
Lippincott, George, 0T
Litterio, Emma, 0S
Liu, Hermes, 0Y
Liu, Zhengfang, 0U, 0W, 0X, 0Y, 0Z
Liubich, Vlad, 0T
Luo, Yandong, 0O
Lupa, Paul, 0L
Ma, Yuansheng, 0K
Madhavan, Sriram, 0C
Madkour, Kareem, 0U
Malik, Arindam, 0N
Mantovani, Valeria, 0S
Mattii, Luca, 03, 09, 0B
May, M., 07
McIntyre, Greg, 0N

Milojevic, D., 03	Xue, Teddy, 0Y
Mocuta, A., 09	Yang, Legender, 0X, 0Z
Mohyeldin, Ahmed, 0F	Ye, Tianchun, 11
Muhsain, Mohamad Fahmi Bin, 0V	Yin, Lianghong, 0K
Muirhead, Jonathan, 0Z	Yu, Shirui, 0U
Nakajima, Fumiharu, 0I	Zhang, Chenming, 0W
Nakamoto, N., 08	Zhang, Hongxin, 0K
Nojima, Shigeki, 0I	Zhang, Meili, 0U
Northrop, G., 08	Zhang, Recoo, 0Z
Ong, Jonathan Yoong Seang, 0E, 0J	Zhang, Zizhuo, 0G
Ou, Odie, 0D	Zhu, ChengYu, 0D
Patelmo, Matteo, 0S	Zhu, Jun, 0W
Pathak, Piyush, 05	Zhu, Xilan, 0G
Perez, Valerio, 0E, 0J	Zhu, Yu, 0Z
Perraud, L., 07	Zou, Elaine, 0X, 0Z
Power, David N., 06	
Qu, Shengrui, 0D	
Quemere, P., 07	
Raghavan, Praveen, 03, 09, 0N	
Riviere-Cazaux, L., 08	
Ronse, Kurt, 0N	
Ryan, E. Todd, 04	
Ryckaert, Julien, 03, 09, 0B, 0N	
Schroeder, Uwe Paul, 0F	
Seo, Jaewoo, 0A	
Shah, Nishant, 0F	
Shang, Shumay, 0K	
Sherazi, Syed Muhammad Yasser, 03, 09, 0B, 0N	
Shin, Youngsoo, 0A, 0R	
Smith, R. S., 04	
Song, Youngsoo, 0R	
Spessot, Alessio, 09, 0B	
Su, Xiaojing, 11	
Su, Yajuan, 11	
Sun, K., 08	
Sun, Yuyang, 0K	
Sweis, Jason, 05, 0L, 0V	
Tan, Ling Ee, 0N	
Teyssedre, H., 07	
Tripathi, Vikas, 0E, 0J	
Triulzi, Benedetta, 0S	
Tseng, I-Lun, 0E, 0J	
Verkest, Diederik, 03, 09, 0B, 0N	
Verma, Rahul, 0G	
Wan, Qijian, 0U, 0W, 0X, 0Y, 0Z	
Wang, Jun, 0D	
Wang, Lynn T.-N., 0C	
Wang, Mudan, 0U	
Wang, Ruoping, 0L	
Watanabe, Yuki, 0I	
Wei, Alexander, 0K	
Wei, Fang, 0W	
Wei, Yayi, 11	
Word, James, 0P, 0Q	
Wu, Chun-Sheng, 10	
Wu, Hall, 0Y	
Wu, Rui, 0K, 0T	
Xu, Wei, 0D	

Conference Committee

Symposium Chair

Bruce W. Smith, Rochester Institute of Technology (United States)

Symposium Co-chair

Will Conley, Cymer, An ASML company (United States)

Conference Chair

Jason P. Cain, Advanced Micro Devices, Inc. (United States)

Conference Co-chair

Chi-Min Yuan, NXP Semiconductors (United States)

Conference Program Committee

Robert Aitken, ARM Inc. (United States)

Luigi Capodieci, KnotPrime Inc. (United States)

Lifu Chang, Qualcomm Inc. (United States)

Ryoung-Han Kim, IMEC (Belgium)

Neal V. Lafferty, Mentor Graphics Corporation (United States)

Ya-Chieh Lai, Cadence Design Systems, Inc. (United States)

Lars W. Liebmann, GLOBALFOUNDRIES Inc. (United States)

Ru-Gun Liu, Taiwan Semiconductor Manufacturing Company Ltd.
(Taiwan)

Andrew R. Neureuther, University of California, Berkeley
(United States)

Shigeki Nojima, Toshiba Corporation (Japan)

David Z. Pan, The University of Texas at Austin (United States)

Chul-Hong Park, SAMSUNG Electronics Company, Ltd.
(Korea, Republic of)

Michael L. Rieger, Consultant (United States)

Vivek K. Singh, Intel Corporation (United States)

Lynn T. Wang, GLOBALFOUNDRIES Inc. (United States)

Session Chairs

- 1 Trends in DPTCO
Jason P. Cain, Advanced Micro Devices, Inc. (United States)
Chi-Min Yuan, NXP Semiconductors (United States)

- 2 Pattern Correction Methods: Joint Session with Conferences 10588 and 10587
Neal V. Lafferty, Mentor, a Siemens Business (United States)
Carlos Fonseca, Tokyo Electron America, Inc. (United States)
- 3 Design-Technology Co-optimization
Ru-Gun Liu, Taiwan Semiconductor Manufacturing Company Ltd. (Taiwan)
Vivek K. Singh, Intel Corporation (United States)
- 4 Layout Optimization
Luigi Capodieci, KnotPrime, Inc. (United States)
Michael L. Rieger, Consultant (United States)
- 5 Design Interactions: Joint Session with Conferences 10585 and 10588
John C. Robinson, KLA-Tencor Corporation (United States)
Ryoung-Han Kim, imec (Belgium)
- 6 Pattern-based Analysis
Lifu Chang, Qualcomm Inc. (United States)
Lars W. Liebmann, GLOBALFOUNDRIES Inc. (United States)
- 7 Advanced Patterning
Shigeki Nojima, Toshiba Corporation (Japan)
Lynn T.-N. Wang, GLOBALFOUNDRIES Inc. (United States)