

FINAL PROGRAM



2014

SOLID-STATE SENSORS, ACTUATORS AND MICROSYSTEMS WORKSHOP

HILTON HEAD

Sonesta Resort ★ Hilton Head, South Carolina

June 8-12, 2014

 www.hh2014.org

Sponsored by the
Transducer Research Foundation, Inc.



Program at a Glance

JUNE 8 SUNDAY	JUNE 9 MONDAY	JUNE 10 TUESDAY	JUNE 11 WEDNESDAY	JUNE 12 THURSDAY
	Breakfast 7:00 am			
	Welcome 7:45 am	Breakfast 7:30 am	Breakfast 7:30 am	Breakfast 7:30 am
	Plenary Speaker I 8:15 am - 9:05 am Oliver Paul <i>University of Freiburg - IMTEK, GERMANY</i>	Plenary Speaker II 8:15 am - 9:05 am Robert Carpick <i>University of Pennsylvania</i>	Plenary Speaker III 8:15 am - 9:05 am Kurt Petersen <i>Band of Angels</i>	Session 8 Late News Papers Oral 8:15 am - 9:45 am
Optional Sunday Workshop Frontiers of Characterization and Metrology for Micro- and Nanosystems 9:00 am - 4:30 pm	Session 1 Biomedical & Cellular Devices 9:05 am - 10:05 am	Session 3 Materials & Surfaces 9:05 am - 9:45 am	Session 6 High-Q Resonators 9:05 am - 10:25 am	
	Break 10:05 am - 10:30 am	Break 9:45 am - 10:10 am		Session 9 Lab Chip & Microfluidics 10:10 am - 11:30 am
	Session 2 Bioassays 10:30 am - 11:30 am	Session 4 Fabrication & Materials 10:10 am - 11:10 am	Break 10:25 am - 10:50 am	
	Poster Preview Session 1 11:30 am - 12:15 pm	Session 5 Magnetic Transducers 11:10 am - 12:10 pm	Session 7 Resonant Systems 10:50 am - 12:10 pm	Networking Lunch 11:30 am - 1:00 pm
	Networking Lunch 12:15 pm - 1:45 pm	Networking Lunch 12:10 pm - 1:40 pm	Poster Preview Session 2 12:10 pm - 12:55 pm	
	Poster Session 1 - Contributed and Late News 1:45 pm - 4:45 pm	Golf and Volleyball Tournaments	Networking Lunch 12:55 pm - 2:25 pm	
			Poster Session 2 - Contributed and Late News 2:25 pm - 5:25 pm	
	Reception and Poster Session 3 - Commercial & Open Posters 6:30 pm - 8:00 pm			
Registration & Welcome Reception 6:00 pm - 9:00 pm		Banquet 7:00 pm - 10:00 pm	Rump Session 8:00 pm - 10:30 pm	

General Information

Meeting Room Logistics

Please contact the Workshop Registration Desk if you find the temperature in the room uncomfortable or you are unable to hear or see because of equipment difficulties.

Information/Message Board

The Information/Message Board will be located near the Workshop Registration Desk. Messages will be posted in this area throughout the Workshop.

Job Market Board

Please visit the Job Market Board also located near the Workshop Registration Desk to see current job opportunities or to place your resume on the board.

Name Badges

All attendees and their guests must wear their name badges to all sessions and social functions.

Smoking

All meeting rooms and seated functions are smoke free. Please regard the smoking policy of the Sonesta Resort and use designated smoking areas only.

Cellular Phones, Beepers, and Watch Alarms

Out of courtesy to our speakers and other attendees, please turn off any cellular phones, pagers and watch alarms during sessions.

Wireless Internet Service

Wireless Internet will be available in the Workshop meeting space in the Sonesta Resort.

- Select "SSAMW" from the list of available networks.
- Once prompted, the Workshop code is: **HiltonHead** (case sensitive)

We ask that you limit your usage to be considerate of other attendees and please logout once you are finished. There is a bandwidth limit of 2 Mbps per device.

Guest Packages

Guest meal packages are available for purchase for all guests of attendees. The package includes the Sunday Welcome Reception, Guest Breakfast (Santee Ballroom 7:30 a.m. – 10:00 a.m.), Lunches, and the Tuesday Banquet. Please visit the Workshop Registration Desk if you would like to purchase a guest package.

Adult guest packages may be purchased for \$225.00 and Child packages (7 - 12 years of age) are available for \$125.00. Children under 6 are free.

Guests and children will not be admitted to social events without a badge. A name badge is required for anyone to attend the meal functions. Children under 6 are free, but will still require a name badge, so please register them as well if you have not already done so. Access will not be permitted without a name badge.

Workshop Social Events

Name badges are required for all Social Events, including guests.

Sunday Welcome Reception

The Welcome Reception will be held Sunday evening, June 8th, 6:00 p.m. - 9:00 p.m. outside in the Pavilion and is sponsored in part by Knowles.

Tuesday Banquet

The Tuesday Banquet will be held on Tuesday, June 10th, 7:00 p.m. - 10:00 p.m. outside in the Pavilion and is sponsored in part by Freescale.

Women in MEMS Breakfast

The Women in MEMS Breakfast will be on Tuesday from 7:15 a.m. - 8:10 a.m. in the Jasper Room, 2nd Floor. Ladies, grab your breakfast and coffee from the Workshop Breakfast Area and join us. Come meet new faces, catch up with old friends, and make connections. Students and first-time attendees are especially encouraged to attend and join the Women in MEMS Network.

Golf Tournament

Tuesday afternoon provides for an open agenda. Why not join the adventuresome and "T" it up at the Annual Hilton Head Workshop Golf Tournament which is sponsored again by Kaplan Breyer Schwartz & Ottesen, LLP. This event is open to all that enjoy the peaceful serenity of lush fairways and manicured greens. The ability to play 9 or 18 holes is also available. You can sign up as a single, pair, threesome or gather a foursome. A summary of the outing, including presentation of awards will be announced at the Rump Session on Wednesday. If you are interested in joining the Golf Tournament, sign up at the Workshop Registration Desk.

Beach Volleyball

The Beach Volleyball, sponsored by Coventor, will be held on Tuesday afternoon between 2:00 p.m. and 5:30 p.m. All levels of play will be integrated into this fun afternoon. If you are interested in joining the Beach Volleyball, please head out to the beach area at the Resort after 2:00 p.m. Coventor will be supplying refreshing drinks and snacks, so come out and play, or just come watch the fun.

Organizing Committee

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Transducer Research Foundation

The Transducer Research Foundation (TRF) is a nonprofit organization whose mission is to stimulate research within the United States in science and engineering, with emphasis on technologies related to transducers, microsystems, and nanosystems, and to foster the exchange of ideas and information between academic, industrial, and government researchers. The founders of TRF were also the founders of this biennial "Workshop on Solid-State Sensors, Actuators, and Microsystems," which began in 1984 under IEEE sponsorship. TRF took over the full sponsorship of the Workshop in 1994. TRF also sponsors other topical Workshops in the microsystems field and supports student development through travel grants that enable students to attend major microsystems Conferences and Workshops worldwide.



If your organization would like to explore any of these options for TRF sponsorship or student grants, please contact someone at the Workshop Registration Desk, or a TRF officer/board member, or visit the web-site www.transducer-research-foundation.org for further information.

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Acknowledgement

TRF would like to thank NIST, iNEMI and MEMS Industry Group for sponsoring the Sunday Frontiers of Characterization and Metrology for Micro- and Nanosystems Workshop. A special thank you to Michael Gaitan, Jason Gorman, and Richard Allen from NIST for developing and conducting the Workshop.



Commercial Support

Special acknowledgement to the Transducer Research Foundation, Inc. and the Analog Devices for their educational grant funding support of this Workshop.



<http://www.transducer-research-foundation.org>

The Transducer Research Foundation, Inc. would also like to thank the following companies for their support, encouragement, and involvement in the 2014 Solid State Sensors, Actuators and Microsystems Workshop.

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Coventor, Inc. is the market leader in automated design solutions for micro-electromechanical systems (MEMS) and virtual fabrication of MEMS and semiconductor devices. More information is available at <http://www.coventor.com>.

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Berkeley Sensor & Actuator Center (BSAC), founded 1986, is the NSF Industry/University Cooperative Research Center for MEMS with 35 member companies and 150 researchers.

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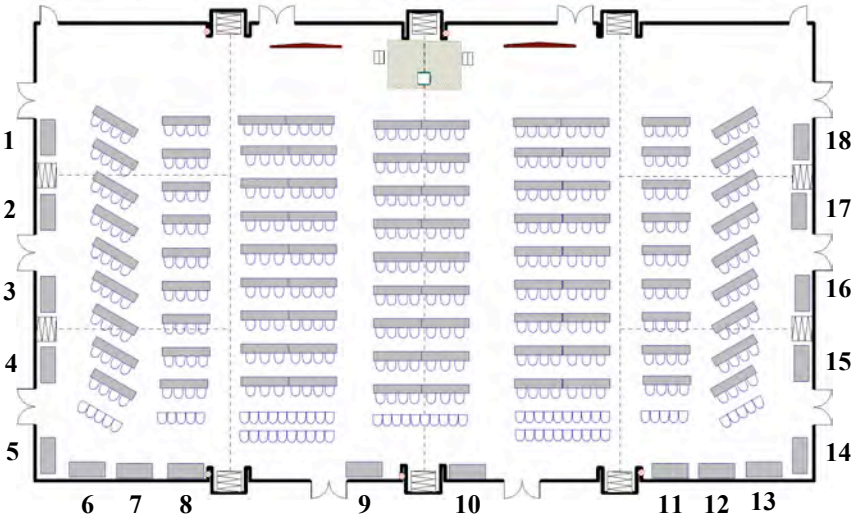
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Tabletop Floorplan

Santee Ballroom



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Sunday, June 8

- 6:00 p.m. - **Registration and Welcome Reception**
9:00 p.m. *Welcome Reception sponsored in part by Knowles*

Monday, June 9

7:00 am **Breakfast**

7:45 am **Welcome**
Mehran Mehregany, *Case Western Reserve University, USA*
Mark G. Allen, *University of Pennsylvania, USA*

Plenary Speaker I

Session Chair: O. Brand, *Georgia Institute of Technology, USA*

8:15 am **MEMS AND MORE FOR THE BRAIN: THE CLUSTER OF EXCELLENCE *BRAINLINKS-BRAINTOOLS* AT THE UNIVERSITY OF FREIBURG 1**
Oliver Paul and P. Ruther
University of Freiburg - IMTEK, GERMANY

Session 1 - Biomedical & Cellular Devices

Session Chair: M. Noh, *Drexel University, USA*

9:05 am **DEVELOPMENT AND *IN VIVO* TESTING OF RECONFIGURABLE NEURAL PROBES FOR CHRONIC ELECTRICAL RECORDING 5**
A. Dighe¹, U.P. Froriep¹, M. Sunshine², A. Ievins², P. Anikeeva¹,
C. Moritz², and J. Voldman¹
¹*Massachusetts Institute of Technology, USA and*
²*University of Washington, USA*

9:25 am **POLYMERIC MICRO-GRIPPER FOR APPLYING MECHANICAL STIMULATION ON THREE-DIMENSIONAL CELL AGGREGATES 9**
Q. Wang, S. Zhao, J.K. Choi, X. He, and Y. Zhao
Ohio State University, USA

9:45 am **NANOARRAY-ENHANCED IMPLANTABLE INTRAOCULAR PRESSURE SENSOR WITH REMOTE OPTICAL READOUT 13**
J.O. Lee¹, K. Huang¹, T.-T. Nguyen², D. Sretavan², and H. Choo¹
¹*California Institute of Technology, USA and*
²*University of California, San Francisco, USA*

10:05 am **Break and Tabletop Exhibits**

Session 2 - Bioassays

Session Chair: D. Horsley, *University of California, Davis, USA*

10:30 am **MEMS DEVICE INTEGRATED WITH VERTICALLY ALIGNED CARBON NANOTUBES FOR VIRUS CAPTURE AND DETECTION** 17
Y.-T. Yeh, N. Perea-Lopez, Y. Tang, B.U. McKellar, R. Harouaka, H. Lu, M. Terrones, and S.-Y. Zheng
Pennsylvania State University, USA

10:50 am **MULTIPLEXED PROTEOMICS USING TWO ORDERS OF MAGNITUDE ENHANCED DIELECTROPHORESIS: A COMPREHENSIVE ELECTRICAL AND ELECTROTHERMAL DESIGN METHODOLOGY** 21
S. Emaminejad, M.T. Barako, R.W. Davis, R.W. Dutton, K.E. Goodson, and M. Javanmard
Stanford University, USA

11:10 am **MICROFLUIDIC BARCODE ASSAY FOR MULTIPLEXED CLINICAL DIAGNOSTICS** 24
R. Lin, A. Skandarajah, R.E. Gerver, D.A. Fletcher, and A.E. Herr
University of California, Berkeley, USA

11:30 am **Poster Preview Session 1**
Session Chair: H. Jerman, *Coherent, Inc., USA*

12:15 pm **Networking Lunch**

1:45 pm - **Poster Session 1 – Contributed and Late News**
4:45 pm Session Chairs: X.-A. Fu, *University of Louisville, USA* and S. Tadigadapa, *Pennsylvania State University, USA*
See page 26 for listing of posters for Session 1

4:45 pm **End of Day**

Tuesday, June 10

7:30 am **Breakfast**

Plenary Speaker II

Session Chair: M. Mehregany, *Case Western Reserve University, USA*

8:15 am **NEEDS AND OPPORTUNITIES FOR NANOTRIBOLOGY
IN MEMS AND NEMS 28**
Robert W. Carpick, G.E. Wabiszewski, and F. Streller
University of Pennsylvania, USA

Session 3 - Materials & Surfaces

Session Chair: M. Gaitan, *National Institute of Standards & Technology, USA*

9:05 am **SILICON MIGRATION OF THROUGH-HOLES IN SINGLE-
AND POLY-CRYSTALLINE SILICON MEMBRANES 32**
J. Stehle^{1,2}, V.A. Hong³, A. Feyh¹, G.J. O'Brien¹, G. Yama¹, O. Ambacher²,
B. Kim¹, and T.W. Kenny³
¹*Robert Bosch Research and Technology Center, USA,*
²*University of Freiburg, GERMANY, and* ³*Stanford University, USA*

9:25 am **IMAGE VALIDATION OF PARALLEL SCANNING TUNNELING
MICROSCOPY WITH A CMOS MEMS PROBE ARRAY 36**
Y. Zhang, Y. Tang, L.R. Carley, and G.K. Fedder
Carnegie Mellon University, USA

9:45 am **Break and Tabletop Exhibits**

Session 4 - Fabrication & Materials

Session Chair: F. Herrault, *HRL Laboratories, USA*

10:10 am **RETAINING HIGH AREAL IN-PLANE MAGNETIC ENERGY
DENSITY OVER LARGE MAGNETIC THICKNESS:
A PERMANENT MAGNETIC MICROLAMINATION
APPROACH BASED ON SEQUENTIAL MULTILAYER
ELECTROPLATING 40**
Y. Li¹, J. Kim², M. Kim², A. Armutlulu², and M.G. Allen¹
¹*University of Pennsylvania, USA and* ²*Georgia Institute of Technology, USA*

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¹Stanford University, USA, ²Robert Bosch RTC, USA, and ³University of Freiburg, GERMANY

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¹University of California, Los Angeles, USA, ²University of California, Berkeley, USA, ³Lawrence Berkeley National Lab, USA, ⁴Johannes Gutenberg-Universität, Mainz, GERMANY, and ⁵California NanoSystems Institute, USA

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¹University of California, Los Angeles, USA and ²California NanoSystems Institute, USA

12:10 pm - **Networking Lunch**
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7:00 pm - **Tuesday Banquet**
 10:00 pm *Tuesday Banquet sponsored in part by Freescale*

Wednesday, June 11

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¹Argonne National Laboratory, USA and ²Michigan State University, USA

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S. Rajaraman, *Axion Biosystems, USA*
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- 6:30 pm - **Poster Session 3 - Commercial & Open Posters**
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P. Loeppert, *Knowles Electronics, USA*
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Thursday, June 12

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R. Wang¹, S.A. Bhawe¹, and K. Bhattacharjee²
¹*Cornell University, USA* and ²*RF Micro Devices, Inc., USA*
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V. Foroutan¹, R. Majumdar¹, O. Mahdavi-pour¹, S.P. Ward², and I. Paprotny¹
¹*University of Illinois at Chicago, USA* and
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¹*Massachusetts Institute of Technology, USA* and
²*King Fahd University of Petroleum and Minerals, SAUDI ARABIA*
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R. Tabrizian, A. Norouzpour-Shirazi, and F. Ayazi
Georgia Institute of Technology, USA
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¹*Purdue University, USA*, ²*NASA Ames Research Center, USA*,
³*Santa Clara University, USA*, ⁴*University of Texas, Austin, USA*
- 10:30 am **A PAPER-BASED MICROBIAL SENSOR ARRAY FOR RAPID SCREENING OF ELECTRICITY-PRODUCING BACTERIA 115**
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¹*State University of New York, USA* and ²*University of Cincinnati, USA*
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¹*Purdue University, USA*, ²*Harvard-MIT Health Sciences and Technology, USA*, and ³*University of Nottingham, UK*
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²*Massachusetts Institute of Technology, USA*
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¹*Carnegie Mellon University, USA and* ²*Electronics Research Institute, EGYPT*
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	³ <i>Lawrence Livermore National Laboratory, USA</i> , and	
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	¹ <i>State University of New York, USA, </i> ² <i>University of Cincinnati, USA, and </i> ³ <i>Syracuse University, USA</i>	

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Wednesday, June 11
6:30 p.m. – 8:00 p.m.

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- C1 3-D VIBRATION AND MOTION TESTING OF DEVICES AND MICROSYSTEMS WITH PICOMETER RESOLUTION USING A NEW LASER DOPPLER VIBROMETRY APPROACH**
D. Oliver¹ and H. Steger²
¹Polytec, Inc, USA and ²Polytec, GmbH, GERMANY
- C2 ELECTRO-MECHANICAL MEMS TESTING**
B. den Hartogh, S. Muntwyler, and F. Beyeler
FemtoTools AG, SWITZERLAND
- C3 FAST COMPUTATIONAL ANALYSIS OF PIEZOMEMS RESONATORS**
S. Maity, M. Kamon, and S. Breit
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- C4 HIGH ASPECT RATIO DEEP SILICON ETCHING IN THE BOSCH(TM) PROCESS AT THE MICRO/NANOSCALE**
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Oxford Instruments, UK
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Y. He and T. Hall
IntelliSense Corporation, USA
- C6 LIONIX - PRODUCT-ENABLING TECHNOLOGY FOR MEMS, MICROFLUIDICS, INTEGRATED OPTICS, AND OPTOFLUIDICS**
J. Walker
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- C7 MASKLESS OPTICAL LITHOGRAPHY SYSTEMS AND APPLICATIONS**
N. Wijnaendts van Resandt
Heidelberg Instruments, USA

- C8 MEMS GYRO WITH SPUTTERED THIN FILM PZT**
E. Whitley¹, T. Takemoto², and G. Fox³
¹*Silicon Sensing Systems, UK*, ²*Silicon Sensing Systems, JAPAN*, and
³*Fox Materials Consulting, USA*
- C9 PECVD BELOW 200° C: EMERGING APPLICATIONS IN MEMS**
K. Buchanan¹, M. Carruthers¹, D. Archard¹, K. Crook¹, St. Burgess¹,
and S. Vargo²
¹*SPTS Technologies, UK* and ²*SPTS Technologies, USA*
- C10 SINGLE-CHIP SCANNING PROBE MICROSCOPES: MICROSCOPIC
MICROSCOPES FOR THE MASSES**
N. Sarkar, G. Lee, D. Strathearn, and R. Mansour
ICSPI Corp., University of Waterloo, CANADA
- C11 SYSTEM MODELING FOR MEMS**
M.A. Maher
SoftMEMS, LLC, USA

Open Posters

- OP1 3D VIBRATION TESTING OF DEVICES & MICROSYSTEMS WITH
PICOMETER RESOLUTION USING A NEW LASER DOPPLER
VIBROMETRY APPROACH**
D.E. Oliver¹ and H. Steger²
¹*Polytec, Inc., USA* and ²*Polytec, GmbH., GERMANY*
- OP2 A HIGH FREQUENCY, LARGE DISPLACEMENT UNDERWATER
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D.J. Hoelzle¹, C.K. Chan², M.B. Scott², and A.C. Rowat²
¹*University of Notre Dame, USA* and
²*University of California, Los Angeles, USA*
- OP3 A MINIMALLY INVASIVE MEMS DRUG DELIVERY IMPLANT FOR
THE TREATMENT OF PROSTATE CANCER**
P. Zachkani¹, J.K. Jackson¹, F.N. Pirmoradi², H.M. Burt¹, and M. Chiao¹
¹*University of British Columbia, CANADA* and
²*University of California Berkeley, USA*
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NANOIMPRINTING TEMPLATES**
X. Wang¹, B. Barry¹, S. Anderson², and X. Zhang¹
¹*Boston University, USA* and ²*Boston University Medical Center, USA*
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S. Dou¹, B.S. Strachan², S.W. Shaw², and J.S. Jensen¹
¹*Technical University of Denmark, DENMARK* and
²*Michigan State University, USA*

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¹*Michigan State University, USA and*
²*Hong Kong University of Science and Technology, CHINA*
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¹*University of Florida, USA and* ²*Boeing, USA*
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University of Texas, Austin, USA
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University of Georgia, USA
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¹*Georgia Institute of Technology, USA and* ²*KWJ Engineering, Inc., USA*
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¹*Boston University, USA and* ²*University of California, San Diego, USA*
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Utah State University, USA
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¹*University of Florida, USA and* ²*Boeing, USA*
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Ambihary Inc., USA
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Cornell University, USA

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¹Georgia Institute of Technology, USA and ²University of Pennsylvania, USA
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University of California, Irvine, USA
- OP18 MICROFABRICATED PERMANENT MAGNETS FOR MEMS**
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University of Florida, USA
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D.L. Kelly², and R. Ghodssi¹
¹University of Maryland, College Park, USA and
²University of Maryland, Baltimore, USA
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¹University of California, Berkeley, USA and
²University of California, San Diego, USA
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¹NASA Goddard Space Flight Center, USA and
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University of Maryland, College Park, USA
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C. Rinaldi, and D.P. Arnold
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