PROCEEDINGS OF SPIE

SPIDigitalLibrary.org/conference-proceedings-of-spie

Front Matter: Volume 9433

, "Front Matter: Volume 9433," Proc. SPIE 9433, Industrial and Commercial Applications of Smart Structures Technologies 2015, 943301 (13 May 2015); doi: 10.1117/12.2196319

SPIE.

Event: SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring, 2015, San Diego, California, United States

PROCEEDINGS OF SPIE

Industrial and Commercial Applications of Smart Structures Technologies 2015

**Kevin M. Farinholt
Steven F. Griffin**
Editors

**9–10 March 2015
San Diego, California, United States**

Sponsored by
SPIE

Cosponsored by
American Society of Mechanical Engineers (United States)

Cooperating Organizations
Intelligent Materials Forum (Japan)
Jet Propulsion Laboratory (United States)
National Science Foundation (United States)

Published by
SPIE

Volume 9433

Proceedings of SPIE 0277-786X, V. 9433

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

Industrial and Commercial Applications of Smart Structures Technologies 2015,
edited by Kevin M. Farinholt, Steven F. Griffin, Proc. of SPIE Vol. 9433, 943301
© 2015 SPIE · CCC code: 0277-786X/15/\$18 · doi: 10.1117/12.2196319

Proc. of SPIE Vol. 9433 943301-1

The papers included 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. The papers published in these proceedings 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 this book:

Author(s), "Title of Paper," in *Industrial and Commercial Applications of Smart Structures Technologies 2015*, edited by Kevin M. Farinholt, Steven F. Griffin, Proceedings of SPIE Vol. 9433 (SPIE, Bellingham, WA, 2015) Article CID Number.

ISSN: 0277-786X

ISBN: 9781628415360

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 © 2015, 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/15/\$18.00.

Printed in the United States of America.

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

SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print. Papers are published as they are submitted and meet publication criteria. A unique citation identifier (CID) number is assigned to each article at the time of the first 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, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four 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. The complete citation is used on the first page, and an abbreviated version on subsequent pages.

Contents

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

USE OF PIEZOELECTRICS IN SMART STRUCTURES

9433 02	Actuators using piezoelectric stacks and displacement enhancers [9433-1]
9433 03	Optimally tuned resonant negative capacitance for piezoelectric shunt damping based on measured electromechanical impedance [9433-2]
9433 04	Mapping of power consumption and friction reduction in piezoelectrically assisted ultrasonic lubrication [9433-3]
9433 05	Geometry adaptive control of a composite reflector using PZT actuator [9433-4]

AEROSPACE APPLICATIONS OF SMART STRUCTURES

9433 07	Stress optimization of leaf-spring crossed flexure pivots for an active Gurney flap mechanism [9433-6]
9433 09	Self-repairing composites for drone air vehicles [9433-8]

ENERGY HARVESTING

9433 0B	Multiphysics modeling and design of Galfenol-based unimorph harvesters [9433-10]
9433 0C	Magnetostrictive vibration damper and energy harvester for rotating machinery [9433-11]

TECHNOLOGIES FOR VIBRATION CONTROL

9433 0D	Integrating electrostatic adhesion to composite structures [9433-12]
9433 0E	Adaptive-passive vibration control systems for industrial applications [9433-13]
9433 0F	Design and testing of a dynamically tuned magnetostrictive spring with electrically controlled stiffness [9433-14]

- 9433 0G **Approach to prevent locking in a spring-damper system by adaptive load redistribution with auxiliary kinematic guidance elements [9433-15]**

APPLICATIONS OF SHAPE MEMORY ALLOYS

- 9433 0H **Computational design optimization of an SMA-based active steerable needle [9433-16]**

POSTER SESSION

- 9433 0W **Energy harvesting to power embedded condition monitoring hardware [9433-31]**
- 9433 0X **Free forming of the gel by 3D gel printer SWIM-ER [9433-32]**
- 9433 0Y **Smart guidewires for smooth navigation in neurovascular intervention [9433-33]**
- 9433 0Z **In-service demonstration of electromagnetic vibration energy harvesting technologies for heavy haul rail applications [9433-34]**
- 9433 10 **Evaluation of conductive concrete for anti-static flooring applications [9433-35]**

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.

Asnani, Vivake M., 0C, 0F	Robertson, Anne M., 0Y
Badescu, Mircea, 02	Saito, Azusa, 0X
Bao, Xiaoqi, 02	Salloum, Rogério, 03
Bar-Cohen, Yoseph, 02	Scheidler, Justin J., 0F
Barry, Matthew M., 0Y	Shayan, Mahdis, 0Y
Bond, Ian P., 0D	Sheritt, Stewart, 02
Booker, Julian D., 07	Siegel, Jake, 0W
Brown, Nathan, 0W	Swaked, Bassam, 10
Chen, Yanfei, 0Y	Tan, Shujun, 05
Chiu, Wing K., 0Z	Tase, Taishi, 0X
Chun, Youngjae, 0Y	Ung, Chandarin, 0Z
Chyu, Minking K., 0Y	Vandewater, Luke A., 0Z
Dapino, Marcelo J., 04, 0B, 0C, 0F	Vrbata, J., 0E
Deng, Zhangxian, 0B, 0C	Walkemeyer, Phillip, 02
Dong, Sheng, 04	Wu, Zhigang, 05
Dry, Carolyn, 09	Yehia, Sherif, 10
Duan, Xinjie, 0Y	Zhou, Yang, 05
Fang, Houfei, 05	
Farinholt, Kevin, 0W	
Freire Gómez, Jon, 07	
Furukawa, Hidemitsu, 0X	
Galea, Steve C., 0Z	
Gehb, Christopher M., 0G	
Gong, Jin, 0X	
Götz, Benedict, 03	
Hassan, Mohamed, 10	
Heath, Callum J. C., 0D	
Heuss, Oliver, 03	
Humphris, Robert, 0W	
Hutapea, Parsaoran, 0H	
Jankowitz, Brian T., 0Y	
Jiang, Shuidong, 05	
Kawakami, Masaru, 0X	
Konh, Bardia, 0H	
Lan, Lan, 05	
Lee, Hyeong Jae, 02	
Lih, Shyh-Shiuh, 02	
Makino, Masato, 0X	
Mayer, Dirk, 03, 0E	
McQuown, Justin, 0W	
Mellor, Phil H., 07	
Melz, Tobias, 0E, 0G	
Moss, Scott D., 0Z	
Okada, Koji, 0X	
Payne, Owen R., 0Z	
Pfeiffer, T., 0E	
Platz, Roland, 0G	
Potter, Kevin D., 0D	
Qaddoumi, Nasser, 10	

Conference Committee

Symposium Chairs

Victor Giurgiutiu, University of South Carolina (United States)
Christopher S. Lynch, University of California, Los Angeles
(United States)

Symposium Co-chairs

Jayanth N. Kudva, NextGen Aeronautics, Inc. (United States)
Theodoros E. Matikas, University of Ioannina (Greece)

Conference Chair

Kevin M. Farinholt, Luna Innovations Inc. (United States)

Conference Co-chair

Steven F. Griffin, Boeing LTS Inc. (United States)

Conference Program Committee

Steven R. Anton, Tennessee Technological University (United States)
Emil V. Ardelean, Schafer Corporation (United States)
Brandon J. Arritt, Air Force Research Laboratory (United States)
Christian Boller, Fraunhofer IZFP (Germany)
Diann E. Brei, University of Michigan (United States)
Alan L. Browne, General Motors Corporation (United States)
Peter C. Chen, NASA Goddard Space Flight Center (United States)
Marcelo J. Dapino, The Ohio State University (United States)
L. Porter Davis, Honeywell Defense and Space Electronic Systems
(United States)
Xiao-Yan Gong, Medical Implant Mechanics LLC (United States)
Ernie Havens, Cornerstone Research Group, Inc. (United States)
Nancy L. Johnson, General Motors Corporation (United States)
Jayanth N. Kudva, NextGen Aeronautics, Inc. (United States)
Amrita Kumar, Acellent Technologies, Inc. (United States)
Donald J. Leo, The University of Georgia (United States)
Ou Ma, New Mexico State University (United States)
Geoffrey P. McKnight, HRL Laboratories LLC (United States)
Tobias Melz, Fraunhofer-Institut für Betriebsfestigkeit und
Systemzuverlässigkeit (Germany)
Christopher Niezrecki, University of Massachusetts Lowell
(United States)

Wieslaw M. Ostachowicz, The Szwedalski Institute of Fluid-Flow Machinery (Poland)
Gyuhae Park, Chonnam National University (Korea, Republic of)
Marc E. Regelbrugge, Rhombus Consultants Group (United States)
W. Lance Richards, NASA Dryden Flight Research Center (United States)
Janet M. Sater, Institute for Defense Analyses (United States)
Henry A. Sodano, University of Florida (United States)
Wieslaw J. Staszewski, AGH University of Science and Technology (Poland)
Edward V. White, The Boeing Company (United States)

Session Chairs

- 1 Use of Piezoelectrics in Smart Structures
Gyuhae Park, Chonnam National University (Korea, Republic of)
- 2 Aerospace Applications of Smart Structures
Steven F. Griffin, Boeing LTS Inc. (United States)
- 3 Energy Harvesting
Kevin M. Farinholt, Luna Innovations Inc. (United States)
- 4 Technologies for Vibration Control
Alan L. Browne, General Motors Corporation (United States)
- 5 Applications of Shape Memory Alloys
Kevin M. Farinholt, Luna Innovations Inc. (United States)
- 6 Commercially Viable Smart Structure Technologies
Alan L. Browne, General Motors Corporation (United States)
- 7 In Memory of Ephraim Garcia I
Donald J. Leo, The University of Georgia (United States)
- 8 In Memory of Ephraim Garcia II
Daniel J. Inman, University of Michigan (United States)
Darren J. Hartl, Texas A&M University (United States)

Introduction

This volume includes technical papers covering research presented at the 2015 SPIE Industrial and Commercial Applications of Smart Structures Technologies conference held in San Diego, California. This conference provides researchers a unique forum to present and discuss mature, or maturing, technologies that are becoming viable solutions to scientific and engineering challenges in government, industrial, and consumer markets. A strong emphasis is placed on the insertion of smart structure technologies in real-world applications through, 1) the development of market-ready products, 2) subcomponent integration into existing systems, 3) modeling toolsets and software, and 4) advanced technology demonstrations that consider realistic environments beyond those of the standard laboratory setting.

The 2015 conference was well attended by academic, government, and industry participants from the Americas, Europe, and Asia. General sessions focused on the use of piezoelectric materials in smart structures and vibration control applications, energy harvesting using active materials, and control applications using shape memory alloys. Thanks go to Alan L. Browne for organizing a special session on technologies that are nearing commercial viability, with focus on several practical and logistical issues that must be addressed in transitioning from development to production stages of this process. This session included talks by Jeffrey Brown from Dynalloy on "SMA actuators: a viable practical technology," Qibing Pei from UCLA on "Large-strain bistable actuation: BSEP polymer materials, actuators, and applications," and Norm Wereley of the University of Maryland, College Park on "Magnetorheological energy absorbers and applications to occupant protection systems."

Several sessions at this year's conference were also organized to honor the memory of Ephraim Garcia from Cornell University, who passed away on September 10, 2014. Dan Inman wrote that "Professor Ephraim Garcia was a remarkable person not to be forgotten. He was extremely clever, had a tremendous work ethic, and lived life with gusto and purpose. Most of us know him for his contributions to our profession. However, he was also a wonderful husband, father, and friend. At times when his wife Maria was interning or starting her practice, Ephraim was 'Mister Mom.' He was really a very remarkable man, able to balance an aggressive and successful career with a dedicated family life."

Ephraim's professional contributions include many excellent papers and ideas. However, he also gave his time to serve the technical community in unselfish ways, first at DARPA, and later as editor of Smart Materials and Structures (SMS). As a DARPA program manager he kicked off the CHAPS program and infused funding into the community to push the technology forward. Then, he turned his attention to the smart wing program and created MAS (Morphing Aircraft Structures)

resulting in a great deal of excitement, the creation of a new company, and a host of fantastic research results. Both of these programs live on in our community as viable and forward-looking research topics. After leaving DARPA and re-establishing his professorial career at Cornell, he took over the leadership of SMS at a difficult time in the journal's history. Ephraim restructured the review process, breathed new life into it, and raised it up into a viable and respected publication venue. Throughout all of these activities he supported our community through constant service to our various conference venues and technical committees, integrating new ideas and making us laugh and enjoy our business.

In his all too short life, he has made a tremendous impact on technology and on his friends and family. He is survived by his wife Maria, his son Isaac, and his daughter Sarah. We will all miss him a great deal. The conference committee would like to thank Dan Inman and Don Leo for their efforts to organize these talks, and the friends and colleagues of Ephraim Garcia who participated in these memorial sessions.

The goal of our conference is to provide the Smart Materials and Structures community a venue for discussing research results and product development narratives, as well as non-technical hurdles that must be surmounted in transitioning technology out of the research environment. While the number of submissions has increased in recent years, more success stories need to be brought before the technical community to motivate and guide developments in the next generation of Smart Structures. Thank you to each of the authors and presenters for your technical contributions this year, and to the program committee and SPIE staff members for your efforts in making the 2015 conference such a success.

Kevin M. Farinholt
Steven F. Griffin