## PROCEEDINGS OF SPIE

# Industrial and Commercial Applications of Smart Structures Technologies 2016

**Steven F. Griffin** *Editor* 

21–22 March 2016 Las Vegas, Nevada, United States

Sponsored by SPIE

Co-sponsored by

Polytec, Inc. (United States) • OZ Optics, Ltd. (United States) • APS Dynamics, Inc. (United States) • The ElectroForce Systems Group of TA ElectroForce Corporation (United States) • The Institute of Physics (United Kingdom) • American Elements (United States)

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

Published by SPIF

Volume 9801

Proceedings of SPIE 0277-786X, V. 9801

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

Industrial and Commercial Applications of Smart Structures Technologies 2016, edited by Steven F. Griffin, Proc. of SPIE Vol. 9801, 980101 ⋅ © 2016 SPIE CCC code: 0277-786X/16/\$18 ⋅ doi: 10.1117/12.2241686

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 SPIEDigitalLibrary.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 Industrial and Commercial Applications of Smart Structures Technologies 2016, edited by Steven F. Griffin, Proceedings of SPIE Vol. 9801 (SPIE, Bellingham, WA, 2016) Six-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic) ISBN: 9781510600423

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 © 2016, 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/16/\$18.00.

Printed in the United States of America.

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



**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 six-digit CID article numbering system structured as follows:

- 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.

### **Contents**

V	Authors
∨ii	Conference Committee

SESSION 1	ACTIVE FLOW CONTROL
9801 02	Enhanced fuel efficiency on tractor-trailers using synthetic jet-based active flow control (Invited Paper) [9801-1]
9801 03	Fluidic actuators for active flow control on airframe [9801-2]
9801 04	Development of in-series piezoelectric bimorph bending beam actuators for active flow control applications [9801-3]
9801 05	Development of piezoelectric-based membranes for synthetic jet actuators: experiments and modeling $[9801\text{-}4]$
SESSION 2	MORPHING AND SMA
9801 06	Toward the bi-modal camber morphing of large aircraft wing flaps: the CleanSky experience [9801-5]
9801 07	KRISTINA: Kinematic rib-based structural system for innovative adaptive trailing edge [9801-6]
9801 08	Distributed electromechanical actuation system design for a morphing trailing edge wing [9801-7]
9801 0A	Modeling of electric resistance of shape memory alloys: self-sensing for temperature and actuation control of active hybrid composites [9801-9]
SESSION 3	INDUSTRIAL APPLICATIONS I
9801 OB	Digital valve for high pressure high flow applications [9801-10]
9801 OC	An ultrasonic horn atomizer with closed loop driving circuit [9801-11]
9801 OE	Self-repairing composite walls for pressurized space habitats [9801-13]
9801 OF	Electroacoustics modeling of piezoelectric welders for ultrasonic additive manufacturing processes [9801-14]
9801 OG	Active vortex generator deployed on demand by size independent actuation of shape memory alloy wires integrated in fiber reinforced polymers [9801-15]

SESSION 4	INDUSTRIAL APPLICATIONS II
9801 OL	Comparison of binary and multi-level logic electronics for embedded systems [9801-21]
SESSION 5	ENERGY HARVESTING
9801 ON	Mechanical motion conversion from reciprocating translation to one-directional rotation for effective energy harvesting [9801-22]
9801 00	Characterization of micro-generators embedded in commercial-off-the-shelf watches for wearable energy harvesting [9801-23]
9801 OP	Characterization of real-world vibration sources with a view toward optimal energy harvesting architectures [9801-24]
9801 OR	Experimental comparison of piezoelectric and magnetostrictive shunt dampers [9801-26]
	POSTER SESSION
9801 OS	On the use of giant magnetostrictive materials in sonic transducers for liquid atomizers [9801-27]
9801 OT	Analytical model of a giant magnetostrictive resonance transducer [9801-28]

#### **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.

Ahmed, Kabir, ON
Amitay, Michael, 02, 04, 05
Amoroso, F., 06, 07
Ansari, S., OT
Asnani, Vivake M., OR
Badescu, Mircea, OB
Bao, Xiaoqi, OB
Bar-Cohen, Yoseph, OB
Bauer, M., 03
Chan, Wilfred K., 04

Chan, Wilffed R., U4
Chen, Kai-Jhong, OC
Chou, Pei-En, OC
Chou, Yuan-Fang, OC
Cinquemani, S., OS, OT
Clingman, Dan J., 04, 05
Concilio, A., 07, 08
Damti, Shirly M., OL
Dapino, Marcelo J., OF, OR
Deng, Zhangxian, OR
Dimino, I., 07, 08

Diodati, G., 08
Dry, Carolyn, 0E
Gallardo, Daniele, 02
Ghodsi, M., 0S, 0T
Gurka, Martin, 0A, 0G
Hall, Jeffery L., 0B
Hehr, Adam, 0F
Hojjat, Y., 0S, 0T
Housley, Kevin W., 05
Hsu, Jui-Mei, 0C
Hübler, Moritz, 0A, 0G
Kakkar, Shantnu, 0O

Hübler, Moritz, 0A, 0G Kakkar, Shantnu, 0O Lee, Soobum, 0N Lewis, Derek, 0B Lin, Qianyu, 0O Lipowski, M., 03 Magnifico, M., 06, 07 Menicovich, David, 02

Meyer, M., 03 Nissle, Sebastian, 0A, 0G

Pecora, R., 06, 07 Rantz, Robert, 0P Roundy, Shad, 0O, 0P Sadeghian, H., 0S Scheidler, Justin J., 0R Schlösser, P., 03 Schueller, M., 03

Schueller, M., 03 Sherrit, Stewart, 0B Sheykholeslami, M., 0S, 0T

Stanley, R. Joe, OL

Wassenaar, J., 0G

Watkins, Steve E., OL

Xue, Tianchena, 00

Volovick, A., 08

Weigel, P., 03

Zivan, L., 08

Proc. of SPIE Vol. 9801 980101-6

#### **Conference Committee**

Symposium Chairs

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

Symposium Co-chairs

**Tribikram Kundu**, The University of Arizona (United States) **Gregory W. Reich**, Air Force Research Laboratory (United States)

Conference Chair

Steven F. Griffin, The Boeing Company (United States)

Conference Co-chair

Alan L. Browne, Retired, General Motors Company (United States)

#### Conference Program Committee

Steven R. Anton, Tennessee Technological University (United States)
Brandon J. Arritt, Air Force Research Laboratory (United States)
Diann E. Brei, University of Michigan (United States)
Peter C. Chen, NASA Goddard Space Flight Center (United States)
Marcelo J. Dapino, The Ohio State University (United States)
Kevin M. Farinholt, Luna Innovations Inc. (United States)
Xiao-Yan Gong, Medical Implant Mechanics LLC (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)
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)

Gyuhae Park, Chonnam National University (Korea, Republic of)W. Lance Richards, NASA Dryden Flight Research Center (United States)

**Janet M. Sater**, Institute for Defense Analyses (United States) **Edward V. White**, The Boeing Company (United States)

#### Session Chairs

- 1 Active Flow Control Steven F. Griffin, The Boeing Company (United States)
- 2 Morphing and SMA Alan L. Browne, Retired, General Motors Company (United States)
- Industrial Applications IAlan L. Browne, Retired, General Motors Company (United States)
- 4 Industrial Applications II **Gyuhae Park**, Chonnam National University (Korea, Republic of)
- 5 Energy HarvestingSteven F. Griffin, The Boeing Company (United States)