

PROCEEDINGS OF SPIE

# ***Smart Materials and Nondestructive Evaluation for Energy Systems IV***

**Theodoros E. Matikas**  
*Editor*

**5–6 March 2018**  
**Denver, Colorado, United States**

*Sponsored by*  
SPIE

*Cosponsored by*  
OZ Optics, Ltd. (United States)  
Polytec, Inc. (United States)

*Cooperating Organizations*  
Jet Propulsion Laboratory (United States)  
Colorado Photonics Industry Association (United States)

*Published by*  
SPIE

**Volume 10601**

Proceedings of SPIE 0277-786X, V. 10601

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

Smart Materials and Nondestructive Evaluation for Energy Systems IV, edited by Theodoros E. Matikas, Proc. of SPIE Vol. 10601, 1060101 · © 2018 SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2326427

Proc. of SPIE Vol. 10601 1060101-1

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](http://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 *Smart Materials and Nondestructive Evaluation for Energy Systems IV*, edited by Theodoros E. Matikas, Proceedings of SPIE Vol. 10601 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

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

ISBN: 9781510616981  
ISBN: 9781510616998 (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](http://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](http://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](http://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

- v *Authors*
- vii *Conference Committee*

---

**SESSION 1 DEVELOPMENT AND APPLICATION OF SMART MATERIALS FOR ENERGY SYSTEMS**

---

- 10601 02 **Optofluidic smart glass with wide angular performance (Keynote Paper)** [10601-1]
- 10601 03 **Passive vibration control of a plate via piezoelectric shunt damping with FEM and ECM** [10601-2]
- 10601 05 **Performance-enhanced triboelectric nanogenerator using polyimide aerogel for energy harvesting and sensing** [10601-4]

---

**SESSION 2 CHARACTERIZATION OF MATERIALS AND NDE/SHM OF ENERGY**

---

- 10601 06 **Turbofan engine performance study under simulated failure and non-traditional flight conditions (Invited Paper)** [10601-5]
- 10601 07 **Experimental ambient vibration-based structural health monitoring in top-tensioned risers** [10601-6]
- 10601 08 **The synergy of ultrasonic experiments, numerical analyses of wave propagation and scattering theories in cementitious materials** [10601-7]
- 10601 09 **Acoustic emission and active sensing capabilities on full-scale nuclear dry cask storage structures** [10601-8]
- 10601 0B **Nondestructive evaluation using eddy current pulsed thermographic imaging of basalt-carbon hybrid fiber-reinforced composite laminates subjected to low-velocity impact loadings (Invited Paper)** [10601-10]

---

**SESSION 3 TECHNIQUES AND MATERIALS FOR ENERGY HARVESTING: WIND ENERGY SYSTEMS**

---

- 10601 0D **Subharmonic orbits and their stability robustness to greatly enhance the bandwidth of bistable vibration energy harvesters** [10601-12]
- 10601 0G **Periodic wind disturbance rejection using robust individual pitch control** [10601-15]

---

**POSTER SESSION**

---

- 10601 0N **Detection of damage in metallic materials using laser Doppler vibrometry** [10601-22]

- 10601 0O **Vibration monitoring of scale model wind turbine blades through optical fiber sensors**  
[10601-23]
- 10601 0P **Novel infrared thermography approach for rapid assessment of damage in aerospace structures** [10601-24]
- 10601 0Q **Development of a nondestructive methodology based on near infrared imaging for the characterization of damage in transparent and semi-transparent aircraft components**  
[10601-25]
- 10601 0R **Fatigue behavior of aluminum structures subjected to corrosion** [10601-26]
- 10601 0S **Stress monitoring of lithium ion cells during cycling to correlate with the electrochemical processes** [10601-27]
- 10601 0U **Characterization of Ni-P-SiC protective coating nanocomposites produced by electrodeposition and thermal spraying via infrared thermography and scanning acoustic microscopy** [10601-29]
- 10601 0V **Towards miniaturization of electronics by developing and characterizing hyperfine solder powders used in printed circuit boards** [10601-30]

# Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five 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.

Abdul-Aziz, Ali, 06  
Aggelis, Dimitrios G., 08  
Aghakhani, Amirreza, 03  
Avdelidis, Nicolas P., 0B  
Badel, Adrien, 0D  
Basdogan, Ipek, 03  
Bayati, I., 0O  
Bayik, B., 07  
Belloli, M., 0O  
Bissler, Robert D., 06  
Bochtis, D., 0U, 0V  
Cazzulani, G., 0O  
Chen, Xu, 0G  
Cinquemani, S., 0O  
Dalla, P. T., 0R, 0U, 0V  
Dassios, K., 0P, 0Q  
De Smet, Lucas, 08  
Druet, Olivier, 0D  
Dunbar, D., 07  
Esmailzadeh, Ebrahim, 05  
Exarchos, D. A., 0N, 0P, 0Q, 0R, 0U, 0V  
Giurguti, Victor, 09  
Goossen, K. W., 02  
Howden, Stephen, 09  
Huguet, Thomas, 0D  
Ibarra-Castaneda, Clemente, 0B  
Iliopoulos, Sokratis N., 08  
Karantzalis, A. E., 0U, 0V  
Kordatou, T. Z., 0N  
Lahe Mottagh, P., 03  
Lallart, Mickaël, 0D  
Lin, Bin, 09  
Liu, Gao, 0S  
Maldague, Xavier, 0B  
Marabelli, S., 0O  
Matikas, T. E., 0N, 0P, 0Q, 0R, 0U, 0V  
Mosanenzadeh, Shahriar Ghaffari, 05  
Naguib, Hani, 05  
Netzelmann, Udo, 0B  
Omenzetter, P., 07  
Osman, Ahmad, 0B  
Saadatania, Zia, 05  
Sarasini, Fabrizio, 0B  
Sfarra, Stefano, 0B  
Stringer, D. Blake, 06  
Tang, J., 0G  
Tragazikis, I. K., 0N, 0R  
Tzetzis, D., 0U, 0V  
Valeske, Bernd, 0B  
van der A, D., 07  
Wang, Guixin, 0S  
Wolfe, Dan, 02  
Yan, Kangping, 0S  
Yu, Lingyu, 09  
Yuan, Yuan, 0G  
Zhang, Hai, 0B  
Zheng, Tianyue, 0S  
Zhou, Shuo, 0S



# Conference Committee

## *Symposium Chairs*

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

## *Symposium Co-chairs*

**Zoubeida Ounaies**, The Pennsylvania State University (United States)  
**Hoon Sohn**, KAIST (Korea, Republic of)

## *Conference Chair*

**Theodoros E. Matikas**, University of Ioannina (Greece)

## *Conference Co-chairs*

**Kara J. Peters**, North Carolina State University (United States)  
**Norbert G. Meyendorf**, Iowa State University of Science and  
Technology (United States)  
**Christopher Niezrecki**, University of Massachusetts Lowell  
(United States)

## *Conference Program Committee*

**Ali Abdul-Aziz**, Kent State University (United States)  
**Nicolas P. Avdelidis**, Université Laval (Canada)  
**George Y. Baaklini**, NASA Glenn Research Center (United States)  
**Leonard Bond**, Iowa State University (United States)  
**Michael Dalichow**, Quality Network Inc. (United States)  
**Dimitrios A. Exarchos**, University of Ioannina (Greece)  
**Peter Heilmann**, arxes-tolina GmbH (Germany)  
**Manfred Johannes**, South African Institute for Non-Destructive Testing  
(South Africa)  
**Vassilios Kappatos**, University of Southern Denmark (Denmark)  
**Michael Kroening**, Pontifícia Universidade Católica do Rio de Janeiro  
(Brazil)  
**Michele Meo**, University of Bath (United Kingdom)  
**Alexander Michaelis**, Fraunhofer IKTS (Germany)  
**Bernd Michel**, Fraunhofer-Institut für Elektronische Nanosysteme  
(Germany)  
**Piotr Omenzetter**, University of Aberdeen (United Kingdom)  
**Stefano Sfarra**, Università degli Studi dell'Aquila (Italy)

**Tadeusz Stepinski**, AGH University of Science and Technology  
(Poland)

**Mark R. Woike**, NASA Glenn Research Center (United States)

**H. Felix Wu**, U.S. Department of Energy (United States)

**Dong-Jin Yoon**, Korea Research Institute of Standards and Science  
(Korea, Republic of)

**Lingyu Yu**, University of South Carolina (United States)

*Session Chairs*

- 1 Development and Application of Smart Materials for Energy Systems  
**Ali Abdul-Aziz**, Kent State University (United States)
- 2 Characterization of Materials and NDE/SHM of Energy  
**Dimitrios A. Exarchos**, University of Ioannina (Greece)
- 3 Techniques and Materials for Energy Harvesting: Wind Energy Systems  
**Nicolas P. Avdelidis**, Université Laval (Canada)