

PROCEEDINGS OF SPIE

Nanosensors, Biosensors, Info-Tech Sensors and 3D Systems 2017

Vijay K. Varadan
Editor

26–29 March 2017
Portland, Oregon, United States

Sponsored by
SPIE

Co-sponsored by
OZ Optics, Ltd. (United States)
Polytec, Inc. (United States)
Fiberguide Industries (United States)
Frontiers Media (Switzerland)

Cooperating Organization
Jet Propulsion Laboratory (United States)

Published by
SPIE

Volume 10167

Proceedings of SPIE 0277-786X, V. 10167

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

Nanosensors, Biosensors, Info-Tech Sensors and 3D Systems 2017, edited by Vijay K. Varadan,
Proc. of SPIE Vol. 10167, 1016701 · © 2017 SPIE · CCC code: 0277-786X/17/\$18
doi: 10.1117/12.2280108

Proc. of SPIE Vol. 10167 1016701-1

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 *Nanosensors, Biosensors, Info-Tech Sensors and 3D Systems 2017*, edited by Vijay K. Varadan, Proceedings of SPIE Vol. 10167 (SPIE, Bellingham, WA, 2017) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510608191

ISBN: 9781510608207 (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 © 2017, 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/17/\$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 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 *Authors*
- ix *Conference Committee*
- xiii *Introduction*

WEARABLE TECHNOLOGY AND HEALTHCARE

- 10167 03 **Wearable nanosensor systems and their applications in healthcare** [10167-2]
- 10167 05 **Left lateral decubitus position on patients with atrial fibrillation and congestive heart failure** [10167-4]
- 10167 06 **Atrial fibrillation and sudden cardiac death: catheter-based sensor and mapping system of the heart** [10167-5]

3D PRINTING AND APPLICATIONS I

- 10167 09 **3D printing of wearable fractal-based sensor systems for neurocardiology and healthcare** [10167-8]
- 10167 0A **3D printing and IoT for personalized everyday objects in nursing and healthcare** [10167-9]
- 10167 0B **Development of low-cost open source 3D gel printer "RepRap SWIM-ER"** [10167-10]

NANOSENSORS AND SYSTEMS I

- 10167 0C **Depth of field extended imaging method based on intensification of time and spatial expansion** [10167-11]
- 10167 0D **Conductive polymer sensor arrays for smart orthopaedic implants** [10167-12]

FABRICATION AND CHARACTERIZATION OF NANOSENSORS AND STRUCTURES I

- 10167 0E **Optical and mechanical properties of cellulose nanopaper structures** [10167-14]
- 10167 0F **Mechanical and electrical properties of calcinated tea-based cellulose composite films** [10167-15]
- 10167 0G **Properties of TEMPO-oxidized cellulose nanofiber by using aqueous counter collision** [10167-16]
- 10167 0H **Feasibility study of cellulose nanofiber alignment by high DC magnetic field** [10167-17]
- 10167 0I **Study of heart-brain interactions through EEG, ECG, and emotions** [10167-18]

KEYNOTE SESSION

10167 0J **Epidermal electronic systems for sensing and therapy** (Keynote Paper) [10167-19]

NANOSENSORS AND SYSTEMS II

10167 0K **Development of a fiber shape polymeric humidity sensor** [10167-20]

10167 0L **Poly ionic liquid-based nano composites for smart electro-mechanical devices** [10167-21]

ENERGY STORAGE AND POWER

10167 0P **Metallic junction thermoelectric device simulations** [10167-26]

10167 0Q **Cellulose/graphene oxide composite for electrode materials of flexible energy devices** [10167-27]

10167 0R **How coupling affects closely packed rectenna arrays used for wireless power transmission** [10167-29]

3D PRINTING DEMONSTRATION SESSION

10167 0T **Smart walking stick for blind people: an application of 3D printer** [10167-32]

10167 0W **3D printing in social education: Eki-Fab and student PBL** [10167-35]

10167 0Z **Polymer-based blood vessel models with micro-temperature sensors in EVE** [10167-38]

3D PRINTING AND APPLICATIONS II

10167 12 **A 3D printing method for droplet-based biomolecular materials** [10167-41]

10167 13 **Inkjet-printed multi-parameter measuring sensor** [10167-42]

NANOSENSORS AND SYSTEMS IV

10167 14 **Military efforts in nanosensors, 3D printing, and imaging detection** [10167-44]

10167 15 **Magnetic nanotubes for drug delivery** [10167-45]

3D PRINTING AND APPLICATIONS III

10167 16 **Energy storage crystalline gel materials for 3D printing application** [10167-30]

10167 17 **Simulation of 3D food printing extrusion and deposition** [10167-46]

- 10167 19 **Direct G-code manipulation for 3D material weaving** [10167-48]
- 10167 1A **The flexibility controlling study for 3D printed splint** [10167-49]
- 10167 1D **SAW based micro- and acousto-fluidics in biomedicine** [10167-52]
- 10167 1E **Design of the mechanical properties of the gel by the 3D gel printer "SWIM-ER"** [10167-53]
- 10167 1G **Direct-writing of copper-based micropatterns on polymer substrates using femtosecond laser reduction of copper (II) oxide nanoparticles** [10167-55]

GRAPHENE NANOSTRUCTURE

- 10167 1H **Photo-electronic current transport in back-gated graphene transistor** [10167-56]
- 10167 1I **Graphene field effect transistor for generating on-chip thermoelectric power** [10167-57]
- 10167 1J **Phononic dispersion of graphene using atomistic-continuum model and spectrally formulated finite element method** [10167-58]

FABRICATION AND CHARACTERIZATION OF NANOSENSORS AND STRUCTURES II

- 10167 1K **Mechanical characterization of cellulose single nanofiber by atomic force microscopy** [10167-59]
- 10167 1L **Elastic wave propagation in in-homogenous peridynamic bar** [10167-60]
- 10167 1M **Band structure computation of polygonal solid-solid phononic crystal with features using frequency domain spectral superelement method** [10167-61]
- 10167 1O **Nanomechanics of carbon nanotubes** [10167-63]
- 10167 1P **Detection of complex molecular samples by low-cost surface enhanced raman spectroscopy (SERS) substrate** [10167-13]

POSTER SESSION

- 10167 1Q **Comparative study of classification algorithms for damage classification in smart composite laminates** [10167-64]
- 10167 1R **Single molecule dynamics of polyproline by using AFM** [10167-65]
- 10167 1S **Portable fiber-optic taper coupled optical microscopy platform** [10167-66]
- 10167 1T **Development of new eardrum-inspired acoustic transducers** [10167-67]
- 10167 1U **Miniaturized accelerometer made with ZnO nanowires** [10167-68]

- 10167 1V **Morphology and dielectric properties of poly vinyl chloride-[multiwalled carbon nanotube-barium titanate] hybrid composite [10167-69]**
- 10167 20 **Effects of heat treatments and UV exposures on mechanical properties of 3D printed acrylonitrile butadiene styrene specimens [10167-74]**
- 10167 21 **Encapsulation of natural ingredient for skin protection via nanoemulsion process [10167-75]**

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.

Ahmed, Kumkum, 0L
Akther, Asma, 0H, 0Q
Alamir, Mohammed, 20
Ali, Md. Ripon, 0T
Alzahrani, Naif, 20, 21
Ameri, Shideh K., 0J
Arai, Fumihito, 0Z
Asano, Yoshihiro, 0A
Asmatulu, Eylem, 21
Asmatulu, Ramazan, 20
Banadaki, Yaser Mohammadi, 1I, 1P
Basher, Samiul, 0B
Booth, Janice C., 14
Brantley, Christina L., 14
Challita, Elio J., 12
Chen, Ling-Chih, 0K
Chen, Xinlu, 1H
Cheng, Yen-Tse, 0K
Chiang, Yu-Hsin, 13
Choi, Eun-sik, 0G, 1V
Choi, Sang H., 0P, 0R
Crutcher, Sihon H., 14
Duzik, Adam J., 0P
Edwards, Eugene, 14
Estroff, Benjamin, 13
Francis, Elizabeth, 1V
Freeman, Eric C., 12
Fukuzawa, Daisuke, 17
Furukawa, Hidemitsu, 0B, 0L, 0T, 0W, 17, 1E, 1R
Geddis, Demetris, 0R
Gong, Jin, 16
Gopalakrishnan, Srinivasan, 1J, 1L, 1M
Ha, Taewoo, 0J
Hai, Le Van, 0G
Hata, Seiichi, 0Z, 1G
Hayakawa, Takeshi, 0Z
Hayakawa, Tomohiko, 0C
Holness, F. Benjamin, 0D
Hou, Hsuan-Chao, 1I, 1P
Huang, Hui, 1S
Hughes, Shawn M., 20
Ikbali, Md. Allama, 0T
Ikeda, Seiichi, 0Z
Ishikawa, Masatoshi, 0C
Ito, Yasuaki, 0Z, 1G
Johnson, James A., 0D
Jung, Gwang-Yong, 1T
Kabir, M. Hasnat, 0T
Kafy, Abdullahil, 0F, 0Q
Kang, Jinmo, 0H
Kawakami, Masaru, 0B, 0L, 0W, 1E, 1R
Khan, Asif, 1Q
Khosla, Ajit, 0B, 0L, 0W
Kim, Gi-Woo, 1T
Kim, Heung Soo, 1Q
Kim, Hyun Chan, 0E, 0H, 1U
Kim, Jaehwan, 0E, 0F, 0G, 0H, 0Q, 1K, 1U, 1V
Kim, Jeong Woong, 0F, 0G, 1K, 1U
Kim, Kyu-Sung, 1T
Ko, Hyun-U, 0F
Koda, S., 19
Kodama, Mai, 0W
Kranz, Michael, 14
Kumar, Prashanth Shyam, 03, 05, 06, 15, 1O
Lee, Jiyun, 1K
Leo, Donald J., 12
Li, Jianyou, 1A
Li, Yaguang, 0F
Lu, Nanshu, 0J
Makino, Masato, 0W, 17
Mao, Yuchen, 16
Maruyama, Hisataka, 0Z
Micolini, Carolina, 0D
Miyagawa, Shoko, 0A
Miyazaki, Takuya, 16
Mizoshiri, Mizue, 0Z, 1G
Mukherjee, Sushovan, 1J, 1M
Murashima, Takahiro, 17
Mutnuri, Venkata S., 1L
Najem, Joseph S., 12
Neas, Brian, 20
Nicolini, Luke, 0J
Ota, Takafumi, 0B, 1E
Ou, Jinping, 1S
Park, Jung Ho, 0H
Patil, Vinay, 21
Pradhan, Aswini K., 1H
Price, Aaron D., 0D
Rahman, Faidur, 0T
Ramasamy, Mouli, 03, 05, 06, 09, 0I, 15, 1D, 1O
Roberts, J. Keith, 14
Ruffin, Paul, 14
Ryoo, Chang-Kyung, 1Q
Saito, Azusa, 0B, 0W, 1E
Sakai, Kazuyuki, 0W
Sakurai, Junpei, 0Z, 1G
Sato, Kei, 0B
Seif, Mohamed, 14

Sharifi, Safura, 1I, 1P
Shishir, MD I. R., 0Q
Song, Kyo D., 0R
Song, Sangho, 1U
Srivastava, Ashok, 1H
Stier, Andrew, 0J
Takamatsu, Kyuichiro, 0B, 1E
Takamatsu, Kyuuichiro, 0W
Tamamushi, Hironori, 1R
Tamate, Hideaki, 0W
Tanaka, Hiroya, 0A, 19, 1A
Tase, Taishi, 0B, 1E
Thomas, Sabu, 1V
Tippabattini, Jayaramudu, 0F, 1V
Tsalagkas, Dimitrios, 0E
Usta, Aybala, 2I
Vanderwall, Adeesha, 2I
Varadan, Vijay K., 03, 05, 06, 09, 0I, 15, 1D, 1O
Wada, Masato, 0W
Walls, Deidra, 0R
Wang, Lihui, 0C
Wang, Pulin, 0J
Wang, Wei-Chih, 0K, 13
Wang, Weiming, 1S
Whitley, Michael, 14
Wu, Chun-Wei, 13
Yoon, Hargsoon, 0R
Yoshioka, Junki, 0A
Yu, Yan, 1S
Yun, Youngmin, 1U
Zhai, Lindong, 0E, 0G, 1K
Zhu, Meifang, 16

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

Vijay K. Varadan, The Pennsylvania State University (United States)

Conference Co-chairs

Hidemitsu Furukawa, Yamagata University (Japan)
Ajit Khosla, Yamagata University (Japan)
Jaehwan Kim, Inha University (Korea, Republic of)
Kyo D. Song, Norfolk State University (United States)
Sang H. Choi, NASA Langley Research Center (United States)
Yongrae Roh, Kyungpook National University (Korea, Republic of)

Conference Program Committee

Anja Boisen, Technical University of Denmark (Denmark)
Christina L. Brantley, U.S. Army Research, Development and Engineering Command (United States)
Eugene Edwards, U.S. Army Research, Development and Engineering Command (United States)
Srinivasan Gopalakrishnan, Indian Institute of Science (India)
Seiich Hata, Nagoya University (Japan)
Taizo Hayashida, JSR Corporation (Japan)
Daniel Hilbich, International Space University (France)
Mamoru Kawakami, Yamagata University (Japan)
Kimiya Komurasaki, The University of Tokyo (Japan)
Hideki Kyogoku, Kindai University (Japan)
Kunik Lee, Federal Highway Administration Turner Fairbank Highway Research Center (United States)
Uhn Lee M.D., Gachon University Gil Medical Center (Korea, Republic of)
Xinxin Li, Shanghai Institute of Microsystem and Information Technology (China)

Yanjian Liao, Chongqing University (China)
Go Murasawa, Yamagata University (Japan)
Hani E. Naguib, University of Toronto (Canada)
Ilkwon Oh, KAIST (Korea, Republic of)
Aswini K. Pradhan, Norfolk State University (United States)
D. Roy Mahapatra, Indian Institute of Science (India)
Paul B. Ruffin, Alabama A&M University (United States)
Ashok Srivastava, Louisiana State University (United States)
Hiroya Tanaka, Keio University (Japan)
Tauno Vaha-Heikkila, VTT Technical Research Center of Finland
(Finland)
Wei-Chih Wang, University of Washington (United States)
Hargsoon Yoon, Norfolk State University (United States)
Ming Zhou, Suzhou Institute of Nano-tech and Nano-bionics (China)

Session Chairs

- 1 Wearable Technology and Healthcare
Vijay K. Varadan, The Pennsylvania State University (United States)
- 2 3D Printing
Ajit Khosla, Yamagata University (Japan)
- 3 3D Printing and Applications I
Ajit Khosla, Yamagata University (Japan)
- 4 Nanosensors and Systems I
Vijay K. Varadan, The Pennsylvania State University (United States)
- 5 Fabrication and Characterization of Nanosensors and Structures I
Jaehwan Kim, INHA University (Korea, Republic of)
- 6 Keynote Session
Vijay K. Varadan, The Pennsylvania State University (United States)
- 7 Nanosensors and Systems II
Jaehwan Kim, Inha University (Korea, Republic of)

- 8 Quantum and Nanoengineering
Kyo D. Song, Norfolk State University (United States)
- 9 Energy Storage and Power
Kyo D. Song, Norfolk State University (United States)
- 10 3D Printing Demonstration Session
Ajit Khosla, Yamagata University (Japan)
Hidemitsu Furukawa, Yamagata University (Japan)
- 11 Nanosensors and Systems III
Vijay K. Varadan, The Pennsylvania State University (United States)
- 12 3D Printing and Applications II
Vijay K. Varadan, The Pennsylvania State University (United States)
- 13 Nanosensors and Systems IV
Mouli Ramasamy, The Pennsylvania State University (United States)
- 14 3D Printing and Applications III
Mouli Ramasamy, The Pennsylvania State University (United States)
- 15 Graphene Nanostructure
Mouli Ramasamy, The Pennsylvania State University (United States)
- 16 Fabrication and Characterization of Nanosensors and Structures II
Mouli Ramasamy, The Pennsylvania State University (United States)

Introduction

This year's conference concentrated on new ideas, technologies, and potential applications across a wide range of disciplines critical to nano-, bio-, and info-tech-based sensors and systems as applied to health monitoring of human and complex systems in engineering and medicine. The focus was on emerging areas of wearable technology, smart textile innovation, 3D printing of sensor systems, thought-controlled devices and systems, mobile wearable healthcare systems, wireless power feedback routines and devices for medical technology, smart optical materials technology, long-life micro-power systems, and thermoelectric energy conversion films and systems.

This is the first time SPIE Smart Structures/NDE held a 3D printing session and demonstration as part of the 2017 Nano-, Bio-, and Info- Tech Sensors and 3D Systems conference held in Portland, Oregon. Our aim for introducing this important technology into this conference was to enable discussion among scientists, researchers, and engineers of novel ideas for its use in healthcare and improving quality of life.

Researchers from academia and industry showcased their accomplishments and inventions in the field of advanced 3D printing to fuel further exploration and advancement in the field. The 3D printing demonstration and presentation sessions drew strong interest among attendees, as sessions included innovative applications of 3D printing technologies focusing on soft robotics, molecular models, food, biosensors, implantable and non-invasive medical devices, IoT in healthcare, and microstructures.

This activity attracted researchers from all over the world. Professor Hidemitsu Furukawa and Dr. Ajit Khosla from Yamagata University in Japan displayed artistic and innovative approaches of using 3D printing to rapidly fabricate high-strength gels and soft materials. They also displayed various modeling techniques to mimic human structures and organs that could be 3D printed. Another interesting breakthrough in 3D printing technique included printing of edible food.

Similarly, researchers from University of Tokyo, Keio University, University of Rajshahi, and Nagoya University demonstrated the effectiveness and usage of 3D printing in IoT, smart sticks for the blind, soft-bodied robotic structures, and human models. One of the demonstrations focused on 3D printing of biosensors and wearable devices for applications in neurocardiology and healthcare. A research group at Penn State demonstrated wireless biosensors based on fractal geometries that could noninvasively record and transmit pathophysiological signals.

Other notable wearable technology talks were given by Mouli Ramasamy and Nanshu Lu of University of Texas. In a keynote on "Can artificial intelligence (AI)

provoke the revolutionary change in the medical field?" Uhn Lee emphasized the future application of engineering and science in medicine. A catheter-based sensor and ablation system with patient video was presented by Varadan.

Based on the tremendous success of the 2017 3D printing sessions, more researchers and scientists are planning to attend and show live demonstrations of some of the most futuristic 3D printing applications in next year's SPIE Smart Structures/NDE conference in Denver. Professor Furukawa said he was impressed by the response and interest and would want to perform live 3D printing demonstrations in Denver. Similarly, Dr. Khosla added that he would want to 3D print edible sushi for the attendees next year.

I thank all the authors and chairs for their contributions to this year's very exciting conference. I also thank SPIE for supporting the introduction of 3D printing into this year's conference and for supporting its continuation at next year's conference in Denver.

Vijay K. Varadan