

PROCEEDINGS OF SPIE

Bioinspiration, Biomimetics, and Bioreplication VIII

Akhlesh Lakhtakia

Editor

5–7 March 2018

Denver, Colorado, United States

Sponsored by

SPIE

Cosponsored by

OZ Optics, Ltd. (United States)

Polytec, Inc. (United States)

Optical Society of Southern California (United States)

Cooperating Organizations

Jet Propulsion Laboratory (United States)

Colorado Photonics Industry Association (United States)

Published by

SPIE

Volume 10593

Proceedings of SPIE 0277-786X, V. 10593

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

Bioinspiration, Biomimetics, and Bioreplication VIII, edited by Akhlesh Lakhtakia,
Proc. of SPIE Vol. 10593, 1059301 · © 2018 SPIE · CCC code:
0277-786X/18/\$18 · doi: 10.1117/12.2326408

Proc. of SPIE Vol. 10593 1059301-1

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 *Bioinspiration, Biomimetics, and Bioreplication VIII*, edited by Akhlesh Lakhtakia, Proceedings of SPIE Vol. 10593 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

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

ISBN: 9781510616820
ISBN: 9781510616837 (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 © 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. 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

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

ix *Authors*
xi *Conference Committee*

INAUGURAL SESSION

10593 02 **Paradigms for biologically inspired design (Keynote Paper)** [10593-1]

FLIGHT I

10593 03 **Bioinspired pitch control using a piezoelectric horizontal tail for rudderless UAVs (Best Student Paper Award)** [10593-2]

10593 04 **Technological demonstration of an adaptive aileron system** [10593-3]

10593 05 **Optimisation design process of a morphing winglet** [10593-4]

MATERIAL STRUCTURES I

10593 07 **Toward multicontrollable metasurfaces** [10593-7]

BIO-OPTICS

10593 0B **Bioinspired invertebrate pest detection on standing crops** [10593-9]

10593 0C **Replication of large-area *Morpho*-color material using flexible mold** [10593-10]

10593 0D **A bioinspired broadband reflector in the VIS-NIR wavelength range** [10593-11]

ENERGY

10593 0F **Photosynthesis as a guide to small scale production of energy from CO₂** [10593-12]

- 10593 OG **Bioinspired pseudo-ductile composite laminates with hierarchical energy absorption mechanism** [10593-13]
- 10593 OH **Investigation of leaf shape and edge design for faster evaporation in biomimetic heat dissipation systems** [10593-14]

ROBOTICS

- 10593 OI **Interactive experiments in a robotics-based platform to simulate zebrafish response to a predator** [10593-15]
- 10593 OJ **Performance analysis of resilient bioinspired structural systems (Best Student Paper Award and SPIE Best Student Paper Award)** [10593-16]

ADHESION

- 10593 OM **Observation of micro-topography of newt toe pads and investigating on wet adhesive properties of microstructured surface of PDMS** [10593-19]
- 10593 ON **A wall-climbing robot using gecko-inspired dry adhesives and underactuated modular connecting mechanism** [10593-20]
- 10593 OO **Adhesive beads** [10593-22]

FLIGHT II

- 10593 OU **Robustness strategies in bio-inspired flight systems: morphology, dynamics and flight control (Invited Paper)** [10593-27]
- 10593 OV **Transition flight control simulations of bioinspired FWMAV with extended unsteady vortex-lattice method** [10593-28]
- 10593 OW **Comparison of bio-inspired flapping foil propulsion systems with rotary propulsion** [10593-29]

SOFT MATTER

- 10593 OY **Bio-inspired passive variable recruitment of fluidic artificial muscles** [10593-31]
- 10593 OZ **Actuation of soft materials through ultrasonic atomization** [10593-32]
- 10593 IO **Characterizing nitinol wire bond strength in silicone for artificial skin muscles** [10593-33]

MATERIAL STRUCTURES II

10593 13 **Versatile strategies for the development of wood-based functional materials (Invited Paper)**
[10593-36]

POSTER SESSION

10593 16 **Using the chemistry of seawater to make functional smart ports** [10593-39]

10593 17 **In-situ coating for CO₂ conversion at tail pipes and in ambient air in which oxygen is given off: it makes coated concrete stronger** [10593-40]

10593 18 **Development of a PVDF based artificial basilar membrane** [10593-41]

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.

Acosta, Felipe J., 0J
Agarwal, Aman, 0W
Akiyama, K., 0U
Amendola, Gianluca, 04, 05
Amoroso, Francesco, 04
Arena, Maurizio, 05
Banerjee, Sourav, 18
Barak Ventura, Roni, 0I
Bryant, Matthew, 0Y
Burgert, Ingo, 13
Chahl, Javaan Singh, 0B
Chapman, Edward M., 0Y
Chen, D., 0U
Chiadini, Francesco, 07, 0D
Colon, Carlos, 0J
Concilio, Antonio, 04, 05
Cord-Cruz, Gabrielle, 0I
Dharwada, Srikanth, 0W
Dimino, Ignazio, 04, 05
Dry, Carolyn M., 0F, 0O, 16, 17
El Khoury, Rana, 0I
Fiumara, Vincenzo, 0D
Frey, Marion, 13
Funderburk, Morgan, 0Z
Gamble, Lawren L., 03
Gong, Ling, 0M
Gruber, Petra, 0H
Han, Jae-Hung, 0V
Hesselberg, T., 02
Hirai, Yoshihiko, 0C
Inman, Daniel J., 03
Ishibashi, Kosei, 0C
Jeffery Hoover, Jan, 0J
Keplinger, Tobias, 13
Kolomenskiy, D., 0U
Kuwahara, Yuji, 0C
Lakhtakia, Akhlesh, 07
Lecce, Leonardo, 04
Lee, Han-Joo, 0Z
Lee, Jong-Wan, 0V
Lenau, T. A., 02
Li, You, 0N
Liu, H., 0U
Liu, Huajian, 0B
Lo Cascio, Marco, 05
Loh, Kenneth J., 0Z
Mazza, Paul, 10
Mei, Tao, 0N
Meo, M., 0G
Metze, A.-L., 02
Milazzo, Alberto, 05
Milenski, Michael, 10
Nakata, T., 0U
Nguyen, Anh Tuan, 0V
Noda, R., 0U
Ohga, Junpei, 0C
Patel, Reena R., 0J
Pecora, Rosario, 04
Perkins, Edward J., 0J
Peters, John F., 0J
Pinto, F., 0G
Porfiri, Maurizio, 0I
Rajagopal, Prabhu, 0W
Riveros, Guillermo A., 0J
Rizzo, F., 0G
Ruberto, Tommaso, 0I
Rupp, Ariana I. K. S., 0H
Saadatzi, Mohammad Nasser, 18
Saadatzi, Mohammadsadegh, 18
Saito, Akira, 0C
Santamaria, Anthony D., 10
Scaglione, Antonio, 0D
Shin, Moochul, 10
Tavaf, Vahid, 18
Thompson, David S., 0J
Ueyama, K., 0U
Wang, Rongchuan, 0N
Wang, Xiaojie, 0M, 0N
Wu, Xuan, 0M, 0N
Yu, Haiwu, 0M

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

Akhlesh Lakhtakia, The Pennsylvania State University (United States)

Conference Co-chairs

Raúl J. Martín-Palma, Universidad Autónoma de Madrid (Spain)
Mato Knez, CIC nanoGUNE Consolider (Spain)

Conference Program Committee

Javaan S. Chahl, University of South Australia (Australia)
Vincenzo Fiumara, Università degli Studi della Basilicata (Italy)
Olaf Karthaus, Chitose Institute of Science and Technology (Japan)
Mathias Kolle, Massachusetts Institute of Technology (United States)
Kostya Kornev, Clemson University (United States)
Bert Müller, Basel University Hospital (Switzerland)
Maurizio Porfiri, NYU Tandon School of Engineering (United States)
Akira Saito, Osaka University (Japan)
Kathleen Stebe, University of Pennsylvania (United States)
Cordt Zollfrank, Technische Universität München (Germany)

Session Chairs

- 1 Inaugural Session
Akhlesh Lakhtakia, The Pennsylvania State University (United States)
- 2 Flight I
Vincenzo Fiumara, Università degli Studi della Basilicata (Italy)
- 3 Material Structures I
Mato Knez, CIC nanoGUNE Consolider (Spain)
Akhlesh Lakhtakia, The Pennsylvania State University (United States)

- 4 Bio-Optics
Petra Gruber, University of Akron (United States)
- 5 Energy
Vincenzo Fiumara, Università degli Studi della Basilicata (Italy)
- 6 Robotics
Torben A. Lenau, Technical University of Denmark (Denmark)
- 7 Adhesion
Andreas Walther, Albert-Ludwigs-Universität Freiburg (Germany)
- 8 Particulate Matter
Mato Knez, CIC nanoGUNE Consolider (Spain)
Akhlesh Lakhtakia, The Pennsylvania State University (United States)
- 9 Flight II
Torben A. Lenau, Technical University of Denmark (Denmark)
- 10 Soft Matter
Tobias Keplinger, ETH Zürich (Switzerland)
- 11 Material Structures II
Kwang Jin Kim, University of Nevada, Las Vegas (United States)
- 12 Tutorial Lecture
Akhlesh Lakhtakia, The Pennsylvania State University (United States)