PROCEEDINGS OF SPIE

Biomimetics and Bioinspiration

Raúl J. Martín-Palma Akhlesh Lakhtakia Editors

2–3 August 2009 San Diego, California, United States

Sponsored and Published by SPIE

Volume 7401

Proceedings of SPIE, 0277-786X, v. 7401

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

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 *Biomimetics and Bioinspiration*, edited by Raúl J. Martín-Palma, Akhlesh Lakhtakia, Proceedings of SPIE Vol. 7401 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X ISBN 9780819476913

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 © 2009, 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/09/\$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, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent 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 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. Numbers in the index correspond to the last two digits of the six-digit CID number.

Contents

- vii Conference Committee
- ix Sub-nanometer resolution for the inspection of reflective surfaces using white light (Plenary Paper) [7405-37]
 W. Jüptner, T. Bothe, Bremer Institut für angewandte Strahltechnik (Germany)

SESSION 1 GENERAL

- 7401 02 Humanlike robots: the upcoming revolution in robotics (Keynote Paper) [7401-01] Y. Bar-Cohen, Jet Propulsion Lab. (United States)
- 7401 03 Drawing inspiration from biological optical systems (Invited Paper) [7401-02] H. D. Wolpert, Bio-Optics (United States)
- 7401 04 **Plant tissue optics: micro- and nanostructures (Invited Paper)** [7401-03] D. W. Lee, Florida International Univ. (United States)

SESSION 2 STRUCTURAL COLORS

- 7401 05 Optical effects of highly curved multilayer structure found in the scale of structurally colored moth (Invited Paper) [7401-04]
 S. Yoshioka, S. Kinoshita, Osaka Univ. (Japan)
- 7401 06 Structural colors, cosmetics, and fabrics (Invited Paper) [7401-05]
 N. Dushkina, Millersville Univ. (United States); A. Lakhtakia, The Pennsylvania State Univ. (United States)
- 7401 07 Approaches to mimic the metallic sheen in beetles [7401-06] T. A. Lenau, M. Aggerbeck, S. Nielsen, Technical Univ. of Denmark (Denmark)
- 7401 08Light extraction from the bioluminescent organs of fireflies [7401-07]A. Bay, J. P. Vigneron, Univ. of Namur (Belgium)

SESSION 3 BIOMECHATRONICS I

- 7401 09 **Biomimetics: determining engineering opportunities from nature (Invited Paper)** [7401-08] F. E. Fish, West Chester Univ. (United States)
- 7401 0A An investigation of viscous-mediated coupling of crickets cercal hair sensors using a scaled up model [7401-10]
 P. S. Alagirisamy, G. Jeronimidis, V. Le Moàl, The Univ. of Reading (United Kingdom)

7401 OB **Possible uses of the layered structure found in the scales of Hoplia coerulea (Coleoptera)** [7401-11]

J.-P. Vigneron, M. Rassart, P. Simonis, J.-F. Colomer, A. Bay, Univ. of Namur (Belgium)

SESSION 3 BIOINSPIRED FABRICATION

- Bio-mimetic hollow scaffolds for long bone replacement (Invited Paper) [7401-13]
 B. Müller, H. Deyhle, Basel Univ. Hospital (Switzerland) and Univ. of Basel (Switzerland)
 F. C. Fierz, Basel Univ. Hospital (Switzerland); S. H. Irsen, Ctr. of Advanced European Studies and Research (Germany); J. Y. Yoon, Basel Univ. Hospital (Switzerland) and Univ. of Basel (Switzerland); S. Mushkolaj, O. Boss, Basel Univ. Hospital (Switzerland); E. Vorndran, U. Geburek, Univ. of Würzburg (Germany); Ö. Degistirici, Ctr. of Advanced European Studies and Research (Germany) and Univ. Hospital Düsseldorf (Germany); M. Thie, Ctr. of Advanced European Studies and Research (Germany) and Univ. Hospital Düsseldorf (Germany); M. Thie, Ctr. of Advanced European Studies and Research (Germany); B. Leukers, Ctr. of Advanced European Studies and Research (Germany); B. Leukers, Ctr. of Advanced European Studies and Research (Germany); F. Beckmann, GKSS Research Ctr. (Germany); F. Witte, Hannover Medical School (Germany)
- Bio-inspired dental fillings [7401-14]
 H. Deyhle, Univ. of Basel (Switzerland) and Basel Univ. Hospital (Switzerland); O. Bunk, Paul Scherrer Institute (Switzerland); S. Buser, Univ. of Basel (Switzerland) and Basel Univ. Hospital (Switzerland); G. Krastl, N. U. Zitzmann, B. Ilgenstein, Univ. of Basel (Switzerland); F. Beckmann, GKSS Research Ctr. (Germany); F. Pfeiffer, Paul Scherrer Institute (Switzerland) and Technical Univ. Munich (Germany); R. Weiger, B. Müller, Univ. of Basel (Switzerland) and Basel Univ. Hospital (Switzerland)

SESSION 5 BIOMECHATRONICS II

7401 OF Biomimetic inspiration from fire and combustion in nature including the bombardier beetle (Invited Paper) [7401-09] A. C. McIntosh, Univ. of Leeds (United Kingdom)

SESSION 6 BIOMIMETIC FABRICATION

- 7401 0G **Oxide-based photonic crystals from biological templates (Invited Paper)** [7401-15] J. W. Galusha, M. R. Jorgensen, The Univ. of Utah (United States); L. R. Richey, J. S. Gardner, Brigham Young Univ. (United States); M. H. Bartl, The Univ. of Utah (United States)
- 7401 OH Towards replication of the exoskeleton of Lamprocyphus augustus for photonic applications [7401-16]
 A. Lakhtakia, The Pennsylvania State Univ. (United States); R. J. Martín-Palma, The Pennsylvania State Univ. (United States) and Univ. Autónoma de Madrid (Spain);
 C. G. Pantano, The Pennsylvania State Univ. (United States)
- 7401 OJ Nanostructured biomimetic moth-eye arrays in silicon by nanoimprint lithography [7401-18] S. A. Boden, D. M. Bagnall, Univ. of Southampton (United Kingdom)

SESSION 7 BIOINSPIRED POLYMERIC STRUCTURES

7401 0K Plasmonic nanoflowers: bioinspired manipulation of plasmonic architectures via active polymers [7401-19]
 B. M. Ross, L. Y. Wu, L. P. Lee, Univ. of California, Berkeley (United States)

Author Index

Conference Committee

Symposium Chairs

David L. Andrews, University of East Anglia Norwich (United Kingdom) **James G. Grote**, Air Force Research Laboratory (United States)

Conference Chairs

Raúl J. Martín-Palma, Universidad Autónoma de Madrid (Spain) Akhlesh Lakhtakia, The Pennsylvania State University (United States)

Session Chairs

- 1 General Raúl J. Martín-Palma, Universidad Autónoma de Madrid (Spain)
- 2 Structural Colors David W. Lee, Florida International University (United States)
- Biomechatronics I
 Yoseph Bar-Cohen, Jet Propulsion Laboratory (United States)
- Bioinspired Fabrication
 Akhlesh Lakhtakia, The Pennsylvania State University (United States)
- 5 Biomechatronics II Akhlesh Lakhtakia, The Pennsylvania State University (United States)
- 6 Biomimetic Fabrication Bert Müller, Basel University Hospital (Switzerland)
- Bioinspired Polymeric Structures
 Jean-Pol Vigneron, Facultes Universitaires Notre Dame de la Paix (Belgium)