

PROCEEDINGS OF SPIE

Multifunctional Materials and Structures II

Russell W. Mailen
Mariantonieta Gutierrez Soto
Fulvio Pinto
Reza Rizvi
Editors

16–18 March 2026
Vancouver, BC, Canada

Sponsored and Published by
SPIE

Volume 13947

Proceedings of SPIE 0277-786X, V. 13947

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

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 *Multifunctional Materials and Structures II*, edited by Russell W. Mailen, Mariantonieta Gutierrez Soto, Fulvio Pinto, Reza Rizvi, Proc. of SPIE 13947, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510698352

ISBN: 9781510698369 (electronic)

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time)

SPIE.org

Copyright © 2026 Society of Photo-Optical Instrumentation Engineers (SPIE).

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 fees. To obtain permission to use and share articles in this volume, visit Copyright Clearance Center 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.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

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

**SPIE. DIGITAL
LIBRARY**

SPIDigitalLibrary.org

Paper Numbering: A unique citation identifier (CID) number is assigned to each article in the Proceedings of SPIE 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

vii *Conference Committee*

PIEZOELECTRIC-BASED MULTIFUNCTIONAL MATERIALS

- 13947 02 **Multifunctional actuator-sensor-systems based on shape memory alloys and electroactive polymers (Invited Paper)** [13947-45]
- 13947 03 **Optimal design of a valveless fluid pump actuated by a piezoelectric stack** [13947-7]
- 13947 04 **Structural design of a conjoined twin ultrasonic piezoelectric actuator achieving multi-degree-of-freedom motorization** [13947-8]

DESIGN AND FABRICATION OF MULTIFUNCTIONAL MATERIALS I

- 13947 06 **Design and mechanics of additive manufactured multifunctional heterogeneous architected materials (HAMs) (Invited Paper)** [13947-1]
- 13947 08 **Machine learning for design of multifunctional architected metamaterials** [13947-3]
- 13947 09 **Development of 3D multifunctional strain sensors based on nanocomposite-coated metamaterials** [13947-4]

DESIGN AND FABRICATION OF MULTIFUNCTIONAL MATERIALS II

- 13947 0A **Cellulose-based dynamically entangled supramolecular assembly (DESA) gels for impact resistance and vibration damping** [13947-46]
- 13947 0B **Temperature-dependent damage modeling of high-strength steel: toward next-generation protective structures** [13947-10]
- 13947 0C **Community-driven design of flood-resilient recovery housing via 3D concrete printing** [13947-11]

MULTIFUNCTIONAL MATERIALS ADDRESSING SOCIETAL ISSUES

- 13947 0E **Laser-induced graphene-based composite membranes for heavy-metal ion removal and water purification** [13947-14]
- 13947 0F **Manufacturing and characterization of stretchable mechanoluminescent devices for energy harvesting and real-time force sensing** [13947-15]

13947 OG **Multifunctional healing composites: a vitrimeric approach to sustainability** [13947-16]

13947 OH **Analyses of water transport in membrane of polymer electrolyte fuel cell (PEMFC)**
[13947-17]

NANOMATERIALS FOR MULTIFUNCTIONAL MATERIALS

13947 OI **Electrochemical performance comparison of laser-induced graphene electrodes with embedded MnO₂ particles or in-situ fabricated MnOx for lithium ion detection** [13947-18]

13947 OK **Mechanics of graphene and 2D material separation in particle-laden supersonic flows**
[13947-20]

13947 OM **Growth of titanium dioxide nanowires on flexible carbon fibers: effect of hydrothermal versus solvothermal solution chemistry on morphology and preliminary electrochemical behavior** [13947-41]

SELF-FOLDING AND ADAPTIVE STRUCTURES

13947 ON **Laser-induced graphene hinges as low-cost, precise actuators for self-folding shape memory polymers** [13947-23]

13947 OO **Applying a machine learning algorithm to better predict folding behavior of shape memory polymer with multiple varying factors** [13947-24]

13947 OP **Softening of super-twisted nematic liquid crystal elastomer fibers** [13947-25]

ADDITIVE MANUFACTURING OF MULTIFUNCTIONAL MATERIALS

13947 OR **In-situ monitoring of geometric drift and thermo-mechanical modeling toward a digital twin for thin-wall fused filament fabrication** [13947-26]

13947 OS **Influence of printing parameters on the mechanical behavior of 3D-printed ABS under gravity-induced conditions** [13947-27]

13947 OT **Mechanical-luminescent metamaterial for mechanical computing** [13947-29]

POSTER SESSION

13947 OZ **Characterization of variable friction mechanism using shape memory polymer** [13947-35]

13947 10 **Enhancing piezoelectric properties of PLA polymers using additives** [13947-36]

- 13947 11 **Development of a miniature rotary piezoelectric actuator using a finite 2D piezoelectric actuator** [13947-37]
- 13947 12 **Developing a game to understand the relationship between human needs and construction material for sustainable co-production** [13947-38]
- 13947 13 **Development of a boundary-driven actuator for plate vibration** [13947-39]
- 13947 14 **Design and verification of an inertial anti-phase hybrid vibration energy harvesting system** [13947-43]
- 13947 15 **Aeroelastic response of chiral lattice airfoils: integrated experimental and finite element assessment of passive morphing** [13947-44]

DIGITAL POSTER SESSION

- 13947 16 **Design, modeling, and testing of a periodic mechanical metamaterial with localized energy absorption for attenuation of lamb wave** [13947-9]