

PROCEEDINGS OF SPIE

# ***Gallium Nitride Materials and Devices XIV***

**Hiroshi Fujioka  
Hadis Morkoç  
Ulrich T. Schwarz**  
*Editors*

**4–7 February 2019  
San Francisco, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 10918**

Proceedings of SPIE 0277-786X, V. 10918

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](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 *Gallium Nitride Materials and Devices XIV*, edited by Hiroshi Fujioka, Hadis Morkoç, Ulrich T. Schwarz, Proceedings of SPIE Vol. 10918 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

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

ISBN: 9781510624788  
ISBN: 9781510624795 (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 © 2019, 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/19/\$18.00.

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](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

vii	<i>Authors</i>
ix	<i>Conference Committee</i>

---

## GROWTH II

10918 0A	<b>Enhanced optical and structural properties of MBE-grown AlGa<sub>N</sub> nanowires on Si substrate by H<sup>+</sup> ion implantation and UV ozone treatment [10918-9]</b>
----------	--

---

## MATERIAL CHARACTERIZATION I

10918 0E	<b>III-nitride vertical resonant cavity light-emitting diodes with hybrid air-gap/AlGa<sub>N</sub>-dielectric distributed Bragg reflectors [10918-13]</b>
10918 0I	<b>Optically pumped room temperature low threshold deep UV lasers grown on native AlN substrates [10918-17]</b>

---

## MATERIAL CHARACTERIZATION II

10918 0M	<b>Green InGa<sub>N</sub>/Ga<sub>N</sub> based LEDs: high luminance and blue shift [10918-21]</b>
10918 0O	<b>Investigation of the device degradation for commercial light-emitting diodes (LEDs) using spatially and time-resolved electro- and photoluminescence [10918-23]</b>
10918 0Q	<b>Analysis on light extraction property of AlGa<sub>N</sub>-based flip-chip ultraviolet light-emitting diodes by the use of self-assembled SiO<sub>2</sub> microsphere array [10918-25]</b>

---

## NANOSTRUCTURES

10918 0Z	<b>New physics in Ga<sub>N</sub> resonant tunneling diodes (Invited Paper) [10918-34]</b>
10918 14	<b>Demonstration of uniform and reliable Ga<sub>N</sub> p-i-p-i-n separate-absorption and multiplication ultraviolet avalanche photodiode arrays with large detection area [10918-39]</b>

---

## ELECTRON DEVICES

10918 16	<b>Vertical power devices enabled by bulk Ga<sub>N</sub> substrates (Invited Paper) [10918-41]</b>
----------	--

10918 17	<b>Degradation physics of GaN-based lateral and vertical devices (Invited Paper)</b> [10918-42]
10918 19	<b>Simple ohmic contact formation in HEMT structures: application to AlGaIn/GaN</b> [10918-44]
10918 1A	<b>Normally-off p-GaN gate InAlN/GaN HEMTs grown on silicon substrates</b> [10918-45]
10918 1B	<b>Electrical and structural characteristics of aged RF GaN HEMTs and irradiated high-power GaN HEMTs with protons and heavy ions</b> [10918-46]

---

#### **LASER DIODES**

---

10918 1D	<b>High-efficiency blue and green laser diodes for laser displays (Invited Paper)</b> [10918-48]
10918 1F	<b>Influence of sandwiched GaN/AlGaIn/GaN lower quantum barrier on crystallinity and luminescence of an asymmetric GaN-based high-power laser diode</b> [10918-50]

---

#### **VCSEL I**

---

10918 1H	<b>Room temperature continuous wave lasing of GaN-based green vertical-cavity surface-emitting lasers (Invited Paper)</b> [10918-52]
----------	--

---

#### **VCSEL II**

---

10918 1J	<b>Recent progress in GaN-based vertical-cavity surface-emitting lasers with lateral optical confinement due to an incorporated curved mirror (Invited Paper)</b> [10918-54]
10918 1L	<b>Influence of Al ion implantation on electrical and optical properties in nitride TJ VCSEL</b> [10918-56]
10918 1M	<b>Development of nanopore-based near ultraviolet vertical-cavity surface emitting lasers</b> [10918-57]

---

#### **MICRO LEDs I**

---

10918 1O	<b>GaN monolithic integration for lighting and display (Invited Paper)</b> [10918-59]
10918 1Q	<b>Advanced solutions for high-performance GaN MicroLED displays (Invited Paper)</b> [10918-61]

---

## MICRO LEDs II

---

- 10918 1R      **Growth of monolithic full-color light-emitting diode and its applications (Invited Paper)**  
[10918-62]

---

## UV LEDs

---

- 10918 1X      **Functional integrity and stable high-temperature operation of planarized ultraviolet-A  $\text{Al}_x\text{Ga}_{1-x}\text{N}/\text{Al}_y\text{Ga}_{1-y}\text{N}$  multiple-quantum-disk nanowire LEDs with charge-conduction promoting interlayer** [10918-68]

---

## LEDs

---

- 10918 22      **Suppression of indium clustering and quantum confined stark effect of InGaN LED on silicon (111)** [10918-73]