

PROCEEDINGS OF SPIE

# ***International Conference on Micro- and Nano-Electronics 2021***

**Vladimir F. Lukichev  
Konstantin V. Rudenko**  
*Editors*

**4–8 October 2021  
Zvenigorod, Russian Federation**

*Organized by*  
Valiev Institute of Physics and Technology of Russian Academy of Sciences (Russian Federation)

*Sponsored by*  
JSC Molecular Electronics Research Institute (Russian Federation)  
TechnoInfo Ltd. (United Kingdom/Russian Federation)  
NIX Company (Russian Federation)

*Published by*  
SPIE

**Volume 12157**

Proceedings of SPIE 0277-786X, V. 12157

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 *International Conference on Micro- and Nano-Electronics 2021*, edited by Vladimir F. Lukichev, Konstantin V. Rudenko, Proc. of SPIE 12157, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510651906

ISBN: 9781510651913 (electronic)

Published by

**SPIE**

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

Telephone +1 360 676 3290 (Pacific Time)

[SPIE.org](http://SPIE.org)

Copyright © 2022 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](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.

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:** 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

ix *Introduction*

---

## OPTOELECTRONIC MATERIALS AND DEVICES

---

- 12157 02 **Picosecond infrared laser crystallization of Ge layers in Ge/Si multi-nanolayers for optoelectronic applications** [12157-20]
- 12157 03 **Aluminum doped thermomigrated silicon channels for high voltage solar cells: structure and electrical properties** [12157-7]
- 12157 04 **Prospects for the use of composite materials in optoelectronic devices** [12157-69]
- 12157 05 **High-performance A<sup>III</sup>B<sup>V</sup> photodetector for on-chip optical interconnects** [12157-56]

---

## THZ DEVICES

---

- 12157 06 **Investigations of the transmission and reflection spectra of THz radiation of magnetic metallic nanowires** [12157-30]
- 12157 07 **Effects of the peak current and valley current of the current-voltage curve in self-excitation and amplification processes in GaAs / AlAs THz resonant tunneling nanostructures** [12157-14]

---

## MEMORY: STRUCTURES AND DEVICES

---

- 12157 08 **Advances in modeling emerging magnetoresistive random access memories: from finite element methods to machine learning approaches (Invited Paper)** [12157-80]
- 12157 09 **Analytic and SPICE modeling of stochastic ReRAM circuits (Invited Paper)** [12157-74]
- 12157 0A **Light sensitive memristors based on GeSi<sub>x</sub>O<sub>y</sub> films with Ge nanoclusters** [12157-18]
- 12157 0B **Investigation of conductive filament growth and rupture in ReRAM structures based on hafnium oxide** [12157-76]
- 12157 0C **Study of inert gas pressure influence on electroforming and resistive switching of TiN-TiO<sub>2</sub>-SiO<sub>2</sub>-W memristors** [12157-17]
- 12157 0D **Effect of electrodes material on the I-V-curve and switching of memristors on the base of electroformed open metal-SiO<sub>2</sub>-metal sandwich structure** [12157-15]

- 12157 OE **Influence of the kind of metal on memristor effect in MIS structures** [12157-38]
- 12157 OF **Specific of magneto-optical response of nanostructures with various shapes and sizes for magnetic memory elaboration** [12157-6]

---

#### **MEMS TECHNOLOGIES AND DEVICES**

---

- 12157 OG **Development and research of a micromechanical accelerometer sensor element** [12157-24]
- 12157 OH **RF MEMS switch with double-clamp and wafer level package with through silicon vias for integration RF MEMS in applications 5G and internet of things** [12157-78]
- 12157 OI **Reliability issues for electrostatically actuated MEMS switch** [12157-23]
- 12157 OJ **A fast membrane actuator in the current stabilization regime** [12157-34]
- 12157 OK **MEMS devices based on self-organizing semiconductors structures** [12157-79]
- 12157 OL **Investigation of the gas-phase deposition of material layers in plasma-vacuum systems for MEMS production processes** [12157-2]
- 12157 OM **Designing thermal MEMS on a system level** [12157-3]
- 12157 ON **FEM simulation of AlN-based MEMS energy harvester** [12157-82]

---

#### **SENSORS: DEVICES, MATERIALS, TECHNOLOGIES**

---

- 12157 OO **Features of the formation of highly sensitive nanoscale films SnO<sub>2</sub> doped with platinum for sensing applications** [12157-92]
- 12157 OP **Sensors based on graphene nanoribbons and polyaniline nanochannels with graphene-graphene oxide contacts formed by ion etching** [12157-58]
- 12157 OQ **Gate-controlled sensing of ammonia by single-layer MoS<sub>2</sub> field-effect transistor** [12157-26]
- 12157 OR **Research of resonance frequencies of silicon membranes for a fiber-optic acoustic receiver** [12157-63]

---

#### **OTHER DEVICES**

---

- 12157 OS **Towards receiving wide-band superconductor antenna unit technology** [12157-28]
- 12157 OT **Design of implantable microprobe for silicon wet bulk micromachining** [12157-72]

---

#### DEVICE MODELING AND SIMULATION

---

- 12157 0U     **Simulation of various nanoelectronic devices based on 2D materials** [12157-12]
- 12157 0V     **Accounting for the body effect in the compact modeling of an “extrinsic” MOSFET drain current in the linear and saturation regimes** [12157-61]
- 12157 0W     **The influence of charge carrier quantum transport and isoenergy surface anisotropy on the high-frequency conductivity of a semiconductor nanolayer** [12157-16]
- 12157 0X     **Quantum drift-diffusion models for dual-gate field-effect transistors based on mono- and bilayer graphene** [12157-13]
- 12157 0Y     **Monte Carlo simulation of picosecond laser irradiation photoresponse of deep submicron SOI MOSFET** [12157-42]
- 12157 0Z     **A universal approach to FET compact modeling: case study for MESFETs and OFETs** [12157-43]

---

#### RADIATION IMPACT ON SEMICONDUCTOR DEVICES

---

- 12157 10     **Long-term irradiation effects in p-MNOS transistor: experiment results** [12157-85]
- 12157 11     **Influence of diffusion hydrogen on the radiation hardness of silicon devices** [12157-44]

---

#### MICRO- AND NANO-ELECTRONIC TECHNOLOGIES

---

- 12157 12     **Investigation of the influence of the parameters of the temporary bonding and thinning operations on the bending of silicon wafers** [12157-27]
- 12157 13     **Numerical study of aperture shape effects in deep cryogenic etching of silicon** [12157-22]
- 12157 14     **High temperature sintering of sol-gel gibbsite film for acoustic membrane** [12157-68]
- 12157 15     **Induced bistable behavior in elements of the thermal reactor at silicon wafer heating in bistability mode** [12157-32]

---

#### TECHNOLOGIES FOR BEOL LEVEL

---

- 12157 16     **Methylated porous low-k materials: critical properties and plasma resistance** [12157-83]

- 12157 17 **Investigation of plasma resistance of the HSQ electronic resist for prototyping of nanoelectronic devices** [12157-101]
- 12157 18 **Cobalt subtractive etch for advanced interconnects** [12157-55]
- 12157 19 **Investigation of the electrophysical and mechanical properties of metallization based on alloys W with Re, Ti, N for high-temperature silicon VLSI** [12157-57]
- 12157 1A **Investigation of the deposition features and characteristics of diffusion-barrier layers of Ti-TiN for metallization in MIS-transistor structures with a vertical channel** [12157-71]
- 12157 1B **Copper filled contact plugs formation** [12157-41]

---

#### MAGNETIC MATERIALS AND STRUCTURES

---

- 12157 1C **Magnetic properties and hyperfine interactions of iron-borate single crystals and nanoparticles** [12157-5]

---

#### ULTRATHIN AND THIN FILMS GROWTH

---

- 12157 1D **Competing mechanisms of strain relaxation in Ge/Si(001) heteroepitaxy** [12157-1]
- 12157 1E **Re-orientation of graphoepitaxial fluorite films towards small-index crystallographic planes** [12157-29]
- 12157 1F **Magnetron deposition of MoS<sub>2</sub> ultrathin films in conditions of magnetic field.** [12157-70]
- 12157 1G **AFM study of the MoS<sub>2</sub> thin films deposited by magnetron sputtering growth initial stage** [12157-111]
- 12157 1H **Atomic layer deposition of thin films of hafnium oxide using Izofaz TM 200-01 system** [12157-75]
- 12157 1I **Investigation of GaAs MBE growth on FIB-modified Si(100)** [12157-59]
- 12157 1J **Formation of nanocrystalline BaTiO<sub>3</sub> thin films by pulsed laser deposition** [12157-60]

---

#### MICROELECTRONIC METROLOGY

---

- 12157 1K **Techniques for analyzing digital elevation models of surface topography of microelectronics objects** [12157-35]
- 12157 1L **Methodology for island surface structures investigation by x-ray photoelectron spectroscopy** [12157-37]

- 12157 1M **Modification of bounded J-Ramp method to monitor reliability and charge degradation of gate dielectric of MIS devices** [12157-31]
- 12157 1N **Research method of the field transistors high frequency parameters using network analyzer** [12157-25]
- 12157 1O **Calibration of step height standards in sub-micrometer range using three-dimensional reconstruction method in a scanning electron microscope** [12157-50]
- 12157 1P **Beam power absolute measurements using the calorimetric method** [12157-40]
- 12157 1Q **Application of methods used in electron spectroscopy spectra interpretation to ion spectroscopy signals analysis** [12157-36]
- 12157 1R **Uncertainty of the linewidth of a nanoobject at control it in a low-voltage SEM** [12157-45]

#### QUANTUM INFORMATICS

---

- 12157 1S **Descriptive complexity of unitary transformations** [12157-4]
- 12157 1T **Elements of satellite quantum network** [12157-66]
- 12157 1U **Quantum tomography for quantum systems optimization** [12157-84]
- 12157 1V **Quantum measurements and high-precision control of quantum states** [12157-54]
- 12157 1W **Quantum memory on multi atom-resonator system** [12157-97]
- 12157 1X **Some properties of maximal trace measure of quantum computer error rate** [12157-81]
- 12157 1Y **On methods of calculation of  $\pi$  on quantum computers** [12157-73]
- 12157 1Z **Sequences of selective rotation operators for three group clustering on qutrits by means of quantum annealing** [12157-21]
- 12157 20 **Bifurcations and catastrophes at the boundaries separating the phases of quantum correlations** [12157-8]
- 12157 21 **Investigations of multiple quantum NMR dynamics of spin dimer on quantum computer** [12157-39]
- 12157 22 **Quantum hashing on the high-dimensional states** [12157-90]
- 12157 23 **Quantum assisted unsupervised data clustering on the basis of neural networks** [12157-94]
- 12157 24 **Quantum algorithm for the shortest superstring problem** [12157-87]

- 12157 25 **Quantum version of self-balanced binary search tree with strings as keys and applications**  
[12157-88]
- 12157 26 **The quantum version of prediction for binary classification problem by ensemble methods**  
[12157-62]
- 12157 27 **Study of the effect of quantum noise on the accuracy of the Schrödinger equation simulation on a quantum computer using the Zalka-Wiesner method** [12157-53]
- 12157 28 **Study of decoherence of a superposition of macroscopic quantum states by means the consideration of a multimode state of a Schrödinger cat** [12157-51]
- 12157 29 **High-fidelity tracking of the evolution of multilevel quantum states** [12157-46]
- 12157 2A **Quantum entanglement in a family of Heisenberg models with the multiple components of Dzyaloshinsky-Moriya and Kaplan-Shekhtman-Entin-Wohlman-Aharony interactions** [12157-10]
- 12157 2B **Measurement of polarization quantum states under chromatic aberration conditions** [12157-47]
- 12157 2C **High-fidelity tomography of fluorescent ion qubits under conditions of limited discrimination between bright and dark levels** [12157-48]
- 12157 2D **Comparative analysis of various protocols for high-precision tomography of qudits** [12157-49]
- 12157 2E **Quantum transistor with multi-qubit memory in an integral waveguide-resonator scheme**  
[12157-95]
- 12157 2F **Quantum memory on atomic frequency comb in a plasmon-polariton waveguide** [12157-100]