

PROCEEDINGS OF SPIE

Gallium Nitride Materials and Devices IV

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**26–29 January 2009
San Jose, California, United States**

Sponsored and Published by
SPIE

Volume 7216

Proceedings of SPIE, 0277-786X, v. 7216

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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 *Gallium Nitride Materials and Devices IV*, edited by Hadis Morkoç, Cole W. Litton, Jen-Inn Chyi, Yasushi Nanishi, Joachim Piprek, Euijoon Yoon, Proceedings of SPIE Vol. 7216 (SPIE, Bellingham, WA, 2009) Article CID Number.

ISSN 0277-786X
ISBN 9780819474629

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

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Introduction

GaN based electronic and optoelectronic devices continue to develop at a blazing speed as reflected by the advances reported at the meeting. Today, the GaN based light emitters adorn the automobiles, traffic lights, moving signs, outdoor displays, handheld electronics, and background lighting in many consumer electronics including flat panel televisions. All LED outdoor lighting applications are already in full swing. Indoor lighting with LEDs is on the way with high brightness large area ($1 \times 1 \text{ mm}^2$) wafer bonded LEDs which produce optical power levels in excess of 1500 mW with efficacies in excess of 100 l/W at high excitation levels. At lower injection levels the efficacies at the research levels are about 200 l/W and are in the target range of increasing number of LED manufacturers. Indoor general lighting applications seem to be a question of time which can be shortened by relaxation of somewhat artificially set color rendering index which appears to be under consideration. The existing wallplug efficiencies certainly bode well for LED use in general lighting which would save much needed energy.

Shorter wavelength LEDs for medical applications, particularly skin ailment treatment, and applications such as water purification as well as short range communication are also being developed. This parallels laser developments in the UV range for similar applications. Driving forces of this kind are paving the way for the development of high AlN mole fraction AlGaIn and AlIn. Significant improvements in the practice and understanding of high mole fraction AlGaIn and AlIn have been made to the point where the optical processes including light polarization properties of the latter have been determined. Combination of pulsed growth modes as well as growth temperatures as high as 1500 °C have been employed along the way.

Developments on the laser front are focused on increasing and decreasing the wavelength of operation, increasing the output power and power efficiency as well as the longevity under high power operation. Already, GaN based lasers are making their presence known with the introduction of Play Station III BluRay technology by Sony for high definition TV. Further improvements in lasers require native GaN substrates and or templates as defects endemic in the case of growth on foreign substrates can be mitigated, allowing researchers to focus on the aforementioned performance parameters as well as the associated facet damage. In terms of the facet damage, the time tested techniques such as leaving a section unpumped by near the emitting facet led to lifetime of over 10,000 hours at 60 mW power operation at room temperature. This performance is sufficient for the above mentioned applications. Output power levels in excess of 1 W from one laser stripe have been achieved for 1 A injection current with a wall plug efficiency of 24%. As mentioned, increased wall plug efficiencies and

extension of the wavelength in both directions are among the problems of interest. The natural progression mimicking GaAs is taking place in GaN as well with electrically injected vertical cavity surface emitting laser development.

Switching gears to FETs, one GaN RF chip is able to produce CW power levels above 700 W at 2GHz and some 10 W in the millimeter wave region for applications in the wireless (base stations) and agile radar. GaN is also advancing at a blazing speed as a high power switching device for applications in hybrid and all electric cars and electric power distribution systems. Hold voltages in excess of 1 kV are now possible with FETs on sapphire and 4 inch silicon substrates. Modified device structures with p-AlGaIn subgate layers led to hold voltages in excess of 10 kV. Coupled with low on resistances, unprecedented figure of merit values are being attained. While GaN has many materials parameters that bode well for these types of devices, piezoelectric, pyroelectric, and ionic nature of GaN coupled with very high drain voltages used bring about unique challenges that must be met. Hot electrons, hot phonons, and plasmon interaction call for the need to find optimum electron concentration while at the same time attaining as high an electron velocity as possible. Much research effort will very likely be devoted to these unique electron physics not present to the same extent in other semiconductors. The next few years will be interesting in that efforts to produce high resistivity GaN wafers for FETs are underway and when fully successful and implemented, much better FETs performance including reduced degradation will ensue.

Another burgeoning application of GaN and GaN based devices is that for sensors. Both chemical and biological, and signal sensors are being developed. On the signal front, the solar blind detectors with detectivities at par with the venerable but bulky photomultiplier tubes have been achieved with emphasis now shifting to avalanche photodiodes with gain. On the chemical and biological detection side, GaN HFETs with functionalized materials on the surface do make very sensitive and compact sensors for chemical agents such as H₂ as well as pH and biological ones which are precursory to ailments such as pancreatic and prostate cancer. Also, the narrow bandgap cousin of GaN, InN, is also getting considerable attention not just as constituent in GaN but also for THz generation.

The SPIE symposium on GaN Materials and Devices is annually organized to disseminate the latest results and provide an opportunity for researchers from around the world to engage in discussions. Many world renowned invited speakers from Asia, Europe and USA set the stage with wide ranging formal discussions. Not to be underestimated is the fact that the meeting served the purpose of getting experts and newcomers together for friendship and informal discussions of issues relevant to GaN and related materials and devices. Such exchanges will undoubtedly play an invaluable role in the propelling the field forward in general and in particular addressing pivotal issues such as

determination and improvement of internal quantum efficiency in GaN and related materials and external quantum efficiency.

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