Our goal is your success

Success story of using SimuLED package for UV LEDs (published studies only)

STR Group

Enhancement of light extraction in UV LEDs

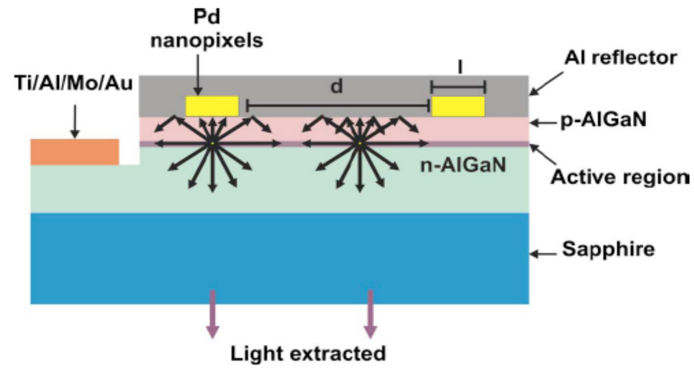
Schematic cross-sectional view of nitride-based nanopixel UV LED with Pd contacts and Al reflector layer

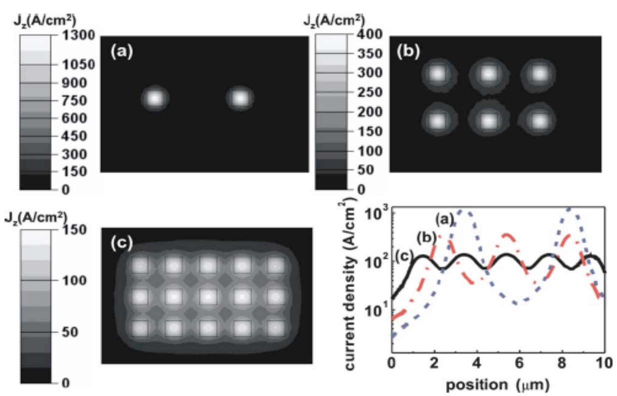
Enhancement of light extraction in ultraviolet light-emitting diodes using nanopixel contact design with Al reflector

N. Lobo,[1,a)] H. Rodriguez,[2] A. Knauer,[2] M. Hoppe,[2] S. Einfeldt,[2] P. Vogt,[1] M. Weyers,[2] and M. Kneissl[1,2]
[1]*Institute of Solid State Physics, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany*
[2]*Ferdinand-Braun-Institute, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany*

(Received 5 January 2010; accepted 4 February 2010; published online 25 February 2010)

We report on a nanopixel contact design for nitride-based ultraviolet light-emitting diodes to enhance light extraction. The structure consists of arrays of Pd ohmic contact pixels and an overlying Al reflector layer. Based on this design a twofold increase in the light output, compared to large area Pd square contacts is demonstrated. Theoretical calculations and experiments reveal that a nanopixel spacing of 1 μm or less is required to enable current overlap in the region between the nanopixels due to current spreading in the p-GaN layer and to ensure current injection into the entire active region. Light emitted in the region between the nanopixels will be reflected by the Al layer enhancing the light output. The dependence of the light extraction on the nanopixel size and spacing is investigated. © *2010 American Institute of Physics*. [doi:10.1063/1.3334721]



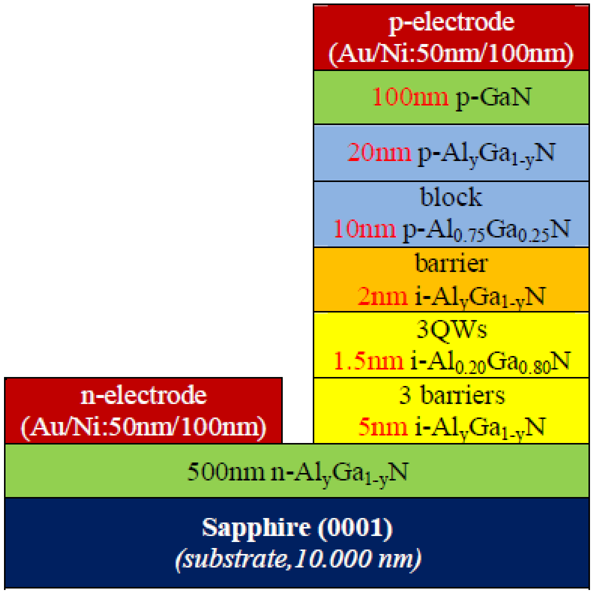


Simulation of the current injection in the active region for nanopixel AlInGaN LEDs with nanopixel size 1x1 μm2 and nanopixel spacing (a) 4 μm, (b) 2 μm, and (c) 1 μm. The total current is constant. In the graph the injection current density as a function of the position along a line through the center of the nanopixels is shown for the different structures.

A nanopixel LED design with an Al reflector was developed resulting in enhanced light extraction in UV LEDs

2010

Effect of dopant concentration in AlGaN blocking layer on operation of UV LED



The modeling structure of UV LED

Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (6): 1054-1058
© Scholarlink Research Institute Journals, 2011 (ISSN: 2141-7016)
jeteas.scholarlinkresearch.org

The Study of Doping Concentration in ALYGA1-YN Block Layer Based on Multi Quantum Well of 313m LED

[1,2]Nguyen Van Hieu and [3]Huynh Hoang Trung

[1]Faculty of Physics and Engineering Physics, University of Science-VNU.HCMC
227 Nguyen Van Cu Str., Dist. 5, Hochiminh City, Vietnam;
[2]Laboratory for Semiconductors, Saigon Hi-Tech Park Labs, Hochiminh City, Vietnam;
[3]Faculty of Foundation Sciences, Univ. of Technical Education HCMC, Vietnam

The structure of UVLED with three multi-quantum wells (MQW) of i$Al_yGa_{1-y}N$ barrier - i$Al_{0.20}Ga_{0.80}N$ QW - i$Al_yGa_{1-y}N$ barrier are studied by the SiLENSe software with various doping concentration of Mg in the block layer.

The intensity of emission spectra from the UV LED structure is shown to be proportional with the doping concentration of Mg in the $Al_yGa_{1-y}N$ barrier layers. The IQE values were found to be stable at $N_d = 5\cdot10^{18}$ cm^{-3}. The emitting wavelength of this structure is around 313 nm. Based on these results, the fabricating process will be done in next time for the deep-UV LED.

2011

Near UV LED grown by atmospheric pressure MOVPE

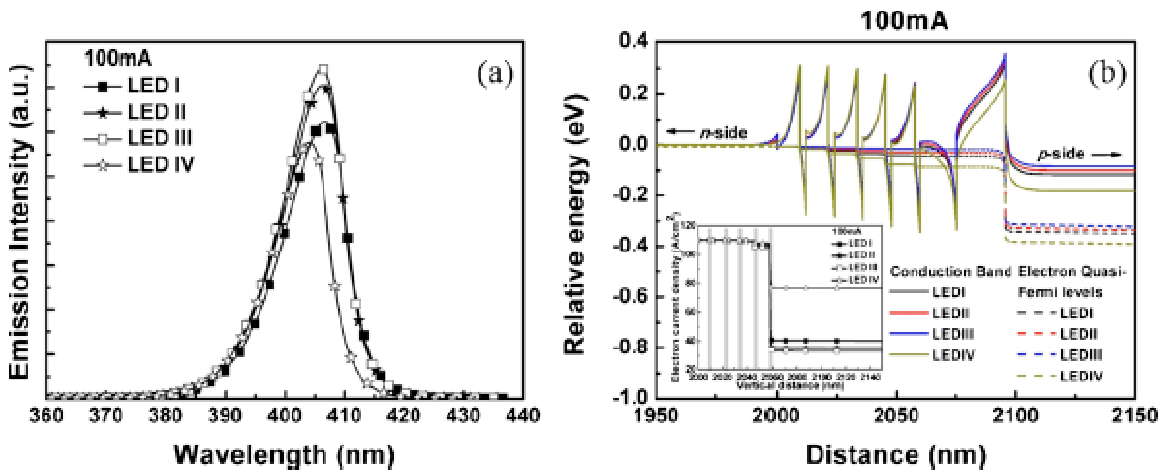
The letter reports a theoretical and experi-mental study on the device performance of near UV LEDs with quaternary AlInGaN QB. The indium mole fraction of AlInGaN QB could be enhanced as the TMGa flow rate was increased. It was found the AlInGaN/InGaN LEDs can reduce forward voltage and improve light output power, compared with conventional GaN QB.

APPLIED PHYSICS LETTERS **98**, 121115 (2011)

The effect of trimethylgallium flows in the AlInGaN barrier on optoelectronic characteristics of near ultraviolet light-emitting diodes grown by atmospheric pressure metalorganic vapor phase epitaxy

Yi-Keng Fu,[1,a)] Ren-Hao Jiang,[1,2] Yu-Hsuan Lu,[1,3] Bo-Chun Chen,[1] Rong Xuan,[1,4] Yen-Hsiang Fang,[1] Chia-Feng Lin,[2] Yan-Kuin Su,[3] and Jenn-Fang Chen[4]
[1]*Electronics and Optoelectronics Research Laboratories, Industrial Technology Research Institute, Hsinchu 31040, Taiwan*
[2]*The Department of Materials Science and Engineering, National Chung Hsing University, Taichung 40227, Taiwan*
[3]*Department of Electrical Engineering, Institute of Microelectronics, National Cheng Kung University, Tainan 70101, Taiwan*
[4]*Department of Electrophysics, National Chiao Tung University, Hsinchu 30010, Taiwan*

(Received 14 December 2010; accepted 6 March 2011; published online 24 March 2011)



(a) The calculated EL spectra and (b) conduction band diagram of these four LEDs at 100 mA current injection. The inset of (b) shows the vertical electron current density profiles near the active regions

Under 100 mA current injection, the LED output power with $Al_{0.089}In_{0.035}Ga_{0.876}N$ QB can be enhanced by 15.9%, compared with LED with GaN QB

2011

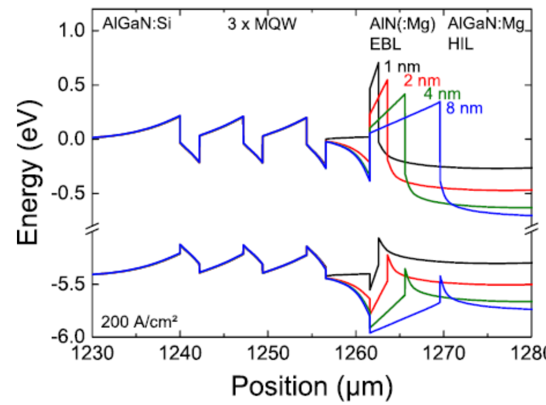
Efficient charge carrier injection

APPLIED PHYSICS LETTERS **105**, 051113 (2014)

Efficient charge carrier injection into sub-250 nm AlGaN multiple quantum well light emitting diodes

Frank Mehnke,[1,a)] Christian Kuhn,[1] Martin Guttmann,[1] Christoph Reich,[1] Tim Kolbe,[1] Viola Kueller,[2] Arne Knauer,[2] Mickael Lapeyrade,[2] Sven Einfeldt,[2] Jens Rass,[1] Tim Wernicke,[1] Markus Weyers,[2] and Michael Kneissl[1,2]
[1]*Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, EW 6-1, 10623 Berlin, Germany*
[2]*Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany*

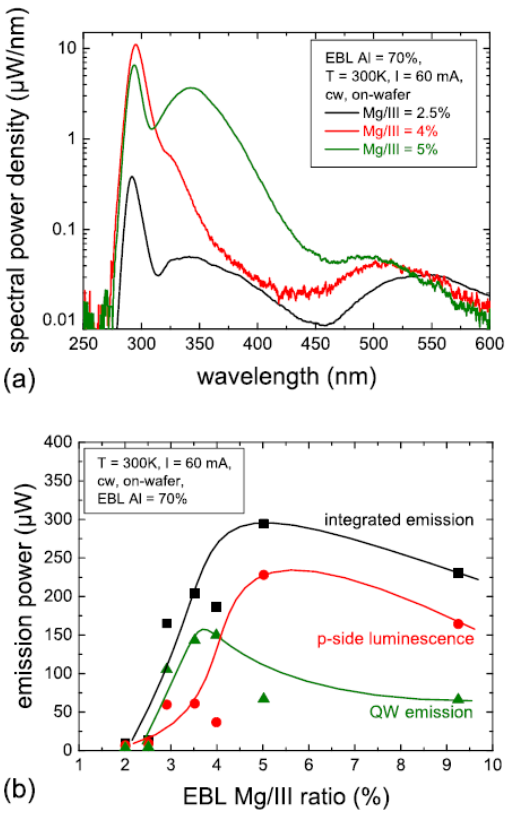
The design and Mg-doping profile of AlN/$Al_{0.7}Ga_{0.3}N$ electron blocking heterostructures (EBH) for AlGaN MQW LEDs emitting below 250 nm was investigated. Inserting an AlN electron blocking layer (EBL) into the EBH, results in increase the quantum well emission power and significant reduction of long wavelength parasitic luminescence. Furthermore, electron leakage was suppressed by optimizing the thickness of the AlN EBL while still maintaining sufficient hole injection. (UV)-C LEDs with very low parasitic luminescence (7% of total emission power) and external quantum efficiencies of 0.19% at 246 nm have been realized. This concept was applied to AlGaN MQW LEDs emitting between 235 nm and 263 nm with EQE ranging from 0.002% to 0.93%. After processing, the authors were able to demonstrate an UV-C LED emitting at 234 nm with 14.5 µW integrated optical output power and an external quantum efficiency of 0.012% at 18.2A/cm^2.



Simulated band diagrams of LED heterostructures with different EBL thicknesses.

2014

Effect of the heterostructure design on injection efficiency and EQE of UV-B LEDs



Typical EL spectra (a) and emission power (b) of UV LEDs with different Mg/III ratios within the EBL. The highest QW luminescence power is achieved with a Mg/III ratio of 4%.

JOURNAL OF APPLIED PHYSICS **117**, 195704 (2015)

Effect of heterostructure design on carrier injection and emission characteristics of 295 nm light emitting diodes

Frank Mehnke,[1,a)] Christian Kuhn,[1] Joachim Stellmach,[1] Tim Kolbe,[2] Neysha Lobo-Ploch,[2] Jens Rass,[2] Mark-Antonius Rothe,[1] Christoph Reich,[1] Nikolay Ledentsov, Jr.,[1] Markus Pristovsek,[1,b)] Tim Wernicke,[1] and Michael Kneissl[1,2]
[1]*Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, EW 6-1, 10623 Berlin, Germany*
[2]*Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany*

The effects of the heterostructure design on the injection efficiency and external quantum efficiency of ultraviolet (UV)-B light emitting diodes (LEDs) have been investigated.

It was found that the functionality of the $Al_xGa_{1-x}N$:Mg electron blocking layer is strongly influenced by its Al mole fraction x and its magnesium doping profile. By comparing LED electroluminescence, quantum well photoluminescence, and simulations of LED heterostructure, the authors were able to differentiate the contributions of injection efficiency and internal quantum efficiency to the external quantum efficiency of UV LEDs.

2015

Solution of electron overflow problem

Journal of
Nanoscience and Nanotechnology
Vol. 15, 4414–4420, 2015
www.aspbs.com/jnn

Simulation Studies of InGaN Based Light-Emitting Diodes to Reduce Electron Overflow Problem by Designing Electron Blocking Layer

Dipika Robidas and D. Arivuoli*
Crystal Growth Centre, Anna University, Chennai 600025, India

When conventional AlGaN EBL is replaced by the $Al_XIn_YGa_{1-X-Y}N$–$Al_{0.15}Ga_{0.85}N$ (X= 0.1, Y = 0.15) EBL the electron potential barrier height increases as well electron leakage can be significantly reduced. The LED structure with AlInGaN/AlGaN EBL significantly increases the internal quantum efficiency by improving the electron hole distribution among the quantum wells of active region and hence results shows enhancement in radiative recombination in QWs. Hence, the observed remarkable reduction in efficiency droop problem with $Al_{0.1}In_{0.15}Ga_{0.75}N/Al_{0.15}Ga_{0.85}N$ EBL is attributed to the increased in the electron potential barrier height near last barrier and Electron blocking layer interface and thereby enhancing the electron blocking efficiency. Furthermore, the weaker electrostatic field in the structure with AlInGaN/AlGaN EBL helps to reduce the tilting of quantum well and as result improving uniform carrier recombinations in active region.

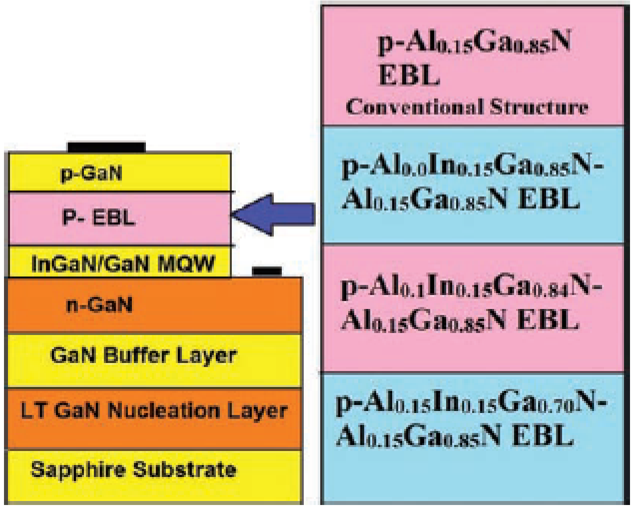


Figure 1. Basic InGaN/GaN MQW LED structure with different p-$Al_XIn_YGa_{1-X-Y}N$–$Al_{0.15}Ga_{0.85}N$ EBL layer.

Table I. Observed effective potential height for the various electron blocking layer structures considered in the simulation work.

Electron blocking layers	Calculated bandgap (eV)	EPBH_ elctron (meV)	EPBH_ hole (meV)
p-$Al_{0.15}Ga_{0.85}N$ EBL (Conventional structure)	3.683	524	405
p-$Al_{0.0}In_{0.15}Ga_{0.85}N$–$Al_{0.15}Ga_{0.85}N$ EBL	3.027	1305	660
p-$Al_{0.1}In_{0.15}Ga_{0.75}N$–$Al_{0.15}Ga_{0.85}N$ EBL	3.9828	926	470
p-$Al_{0.15}In_{0.15}Ga_{0.70}N$–$Al_{0.15}Ga_{0.85}N$ EBL	3.8515	820	465

2015

A strategy for increasing the overlap integral of electron and hole wave functions

Applied Physics Express **10**, 015802 (2017)
https://doi.org/10.7567/APEX.10.015802

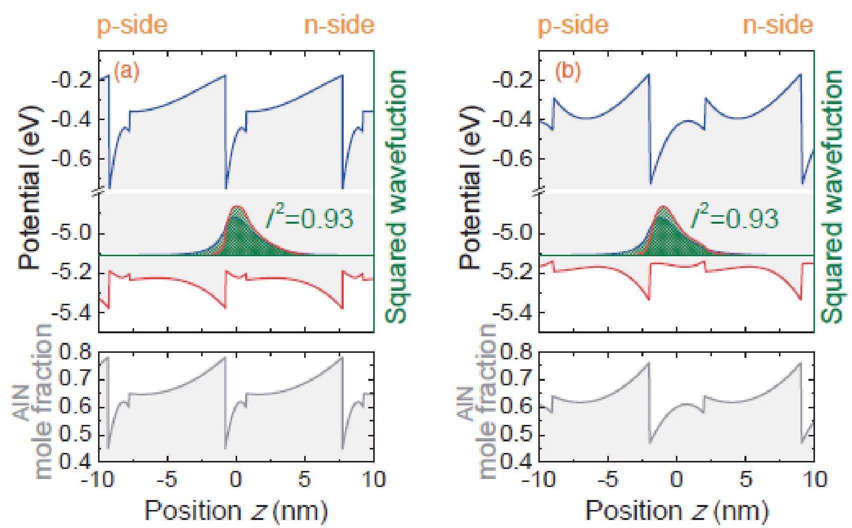
A design strategy for achieving more than 90% of the overlap integral of electron and hole wavefunctions in high-AlN-mole-fraction $Al_xGa_{1-x}N$ multiple quantum wells

Kazunobu Kojima[1], Kentaro Furusawa[1], Yoshiki Yamazaki[1], Hideto Miyake[2,3], Kazumasa Hiramatsu[3], and Shigefusa F. Chichibu[1]

[1]*Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai 980-8577, Japan*
[2]*Graduate School of Regional Innovation Studies, Mie University, Tsu 514-8507, Japan*
[3]*Department of Electrical and Electronic Engineering, Mie University, Tsu 514-8507, Japan*

Received September 23, 2016; accepted December 1, 2016; published online December 21, 2016

Figures (a) and (b) show the optimized band profiles and wavefunctions of the $Al_xGa_{1-x}N$=$Al_yGa_{1-y}N$ QWs of L_w being 1.5 and 4.0 nm, respectively. In the case of L_w = 1.5 nm, I^2 reaches 93% as shown in Fig. 2(a). This value is far greater than that of standard or LCM (linear compositional modulation) cases. In addition, such a high I^2 (93%) is maintained even for thicker QWs with L_w = 4.0 nm. Such a high I^2 has never been obtained for standard or LCM cases.



2017

Optimization of structure parameters for deep UV LEDs

Schematic diagram of optimized structure


Superlattices and Microstructures 112 (2017) 339–352

Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlattices

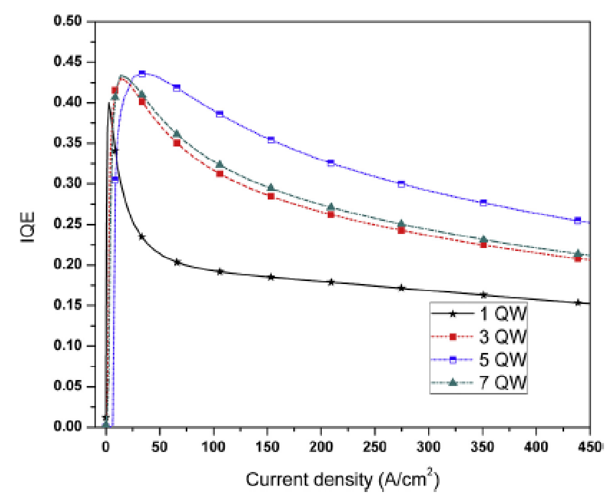
Optimization of structure parameters for highly efficient AlGaN based deep ultraviolet light emitting diodes

Ramit Kumar Mondal [a, c], Vijay Chatterjee [a, *], Sumitra Singh [b], Sk Masiul Islam [a], Suchandan Pal [a]

[a] Optoelectronics and MOEMS Group, CSIR, CEERI, Pilani, Rajasthan, 333031, India
[b] Flexible and Non – Silicon Electronics Group, CSIR, CEERI, Pilani, Rajasthan, 333031, India
[c] Academy of Scientific and Innovative Research (AcSIR), CSIR-CEERI Campus, Pilani 333031, India

A systematic approach has been applied to study the variation of different crucial factors which have great influence on the device performance. In order to achieve highly efficient and optimized device structure variations have been made in the number of quantum well and thickness of the quantum well.

Compositional analysis of Al content in the electron blocking layer and the barrier region have been explored and optimized.



Internal Quantum Efficiency (IQE) Vs Injection current with variation of number of QWs

2017

UV LED with uniform emission pattern

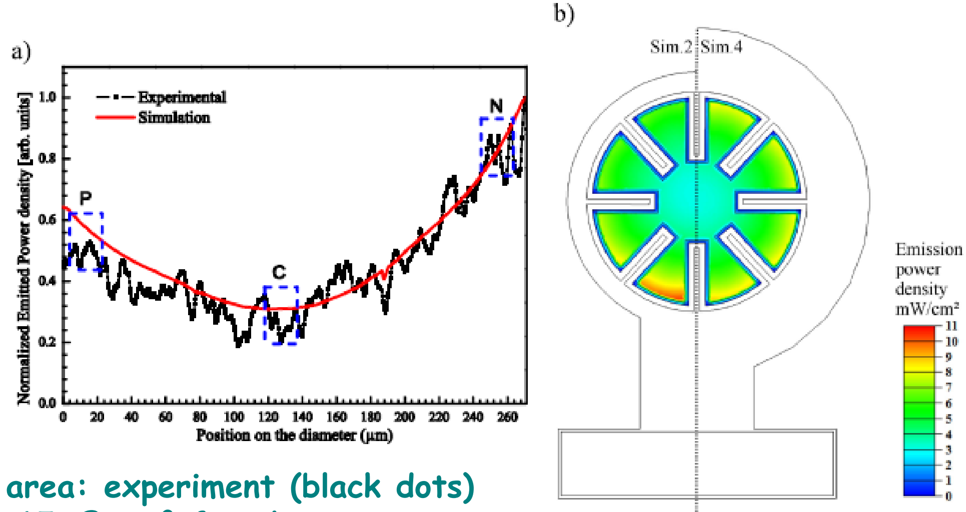
IOP Publishing — Semiconductor Science and Technology
Semicond. Sci. Technol. 32 (2017) 045019 (8pp) https://doi.org/10.1088/1361-6641/aa5a7a

Design considerations for AlGaN-based UV LEDs emitting near 235 nm with uniform emission pattern

Mickael Lapeyrade[1,3], Johannes Glaab[1], Arne Knauer[1], Christian Kuhn[2], Johannes Enslin[2], Christoph Reich[2], Martin Guttmann[2], Frank Mehnke[2], Tim Wernicke[2], Sven Einfeldt, Markus Weyers[1] and Michael Kneissl[2]

[1] Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, D-12489 Berlin, Germany
[2] Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, EW 6-1, D-10623 Berlin, Germany

3D electro-thermal simulations of the current spreading have been performed to optimize the layout of the deep UV LEDs. The results of the simulations indicate that the best way to improve the current density uniformity is to decrease the n-contact resistivity.



(a) Emission power line-scans across the active area: experiment (black dots) and simulation (red line) with 0.3 Ω cm² and 0.15 Ω cm² for the n-contact and p-contact resistivity, respectively, (b) simulated 2D map of the emission power density corresponding to the data shown in (a).

2017

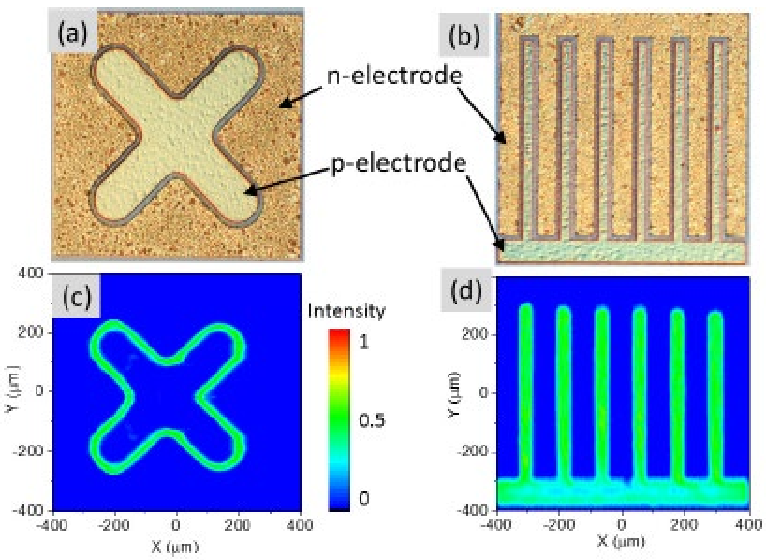
Flip-Chip DUV LEDs

IOP Publishing
Journal of Physics D: Applied Physics
J. Phys. D: Appl. Phys. **51** (2018) 035103 (5pp)
https://doi.org/10.1088/1361-6463/aa9e0e

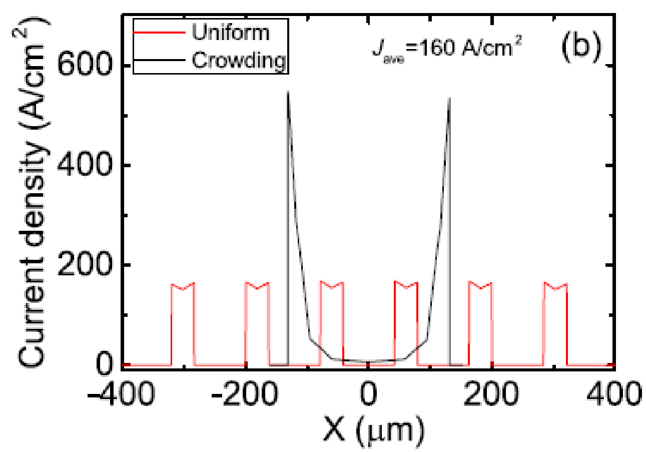
Current crowding and self-heating effects in AlGaN-based flip-chip deep-ultraviolet light-emitting diodes

Guo-Dong Hao[1], Manabu Taniguchi[1], Naoki Tamari[1,2] and Shin-ichiro Inoue[1]

[1] Advanced ICT Research Institute, National Institute of Information and Communications Technology (NICT), Kobe 651-2492, Japan
[2] Tsukuba Research Laboratories, Tokuyama Corporation, Tsukuba, Ibaraki 300-4247, Japan



Microscope images of the electrode geometry for (a) LED-I and (b) LED-II. Measured optical emission pattern from the rear surface of chips in (c) LED-I and (d) LED-II. The average current density is approximately 80 A cm^{-2} for both DUV LEDs.



Local current density along the x-direction for LED-I and LED-II at y = 0.

The results showed that self-heating should be the main origin of the decreased efficiency in the LED with current crowding. The obtained current spreading length in the n-AlGaN current spreading layer was much smaller than that in conventional InGaN-based LEDs. By shortening the p-electrode width from 160 to 40 μm, the crowding issue was greatly alleviated and the current was able to spread uniformly through the entire mesa region.

2018

Deep UV LED with graded superlattice EBL

Check for updates

Cite this: *RSC Adv.*, 2018, **8**, 35528

Improved carrier injection of AlGaN-based deep ultraviolet light emitting diodes with graded superlattice electron blocking layers

Byeongchan So, Jinwan Kim, Taemyung Kwak, Taeyoung Kim, Joohyoung Lee, Uiho Choi and Okhyun Nam*

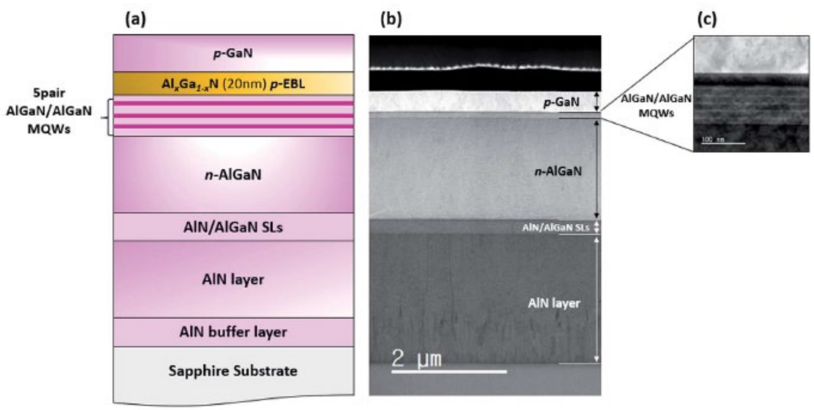
Received 21st August 2018
Accepted 9th October 2018

DOI: 10.1039/c8ra06982d

rsc.li/rsc-advances

A DUV-LED with a graded superlattice electron blocking layer (GSL-EBL) is demonstrated to show improved carrier injection into the multi-quantum well region. The structures of modified EBLs are designed *via* simulation. The simulation results show the carrier behavior mechanism of DUV-LEDs with a single EBL (S-EBL), graded EBL (G-EBL), and GSL-EBL. The variation in the energy band diagram around the EBL region indicates that the introduction of GSL-EBL is very effective in enhancing carrier injection. Besides, all DUV-LEDs emitting at 280 nm are grown in the high temperature metal organic chemical deposition system. It is confirmed that the optical power of the DUV-LED with the GSL-EBL is significantly higher than that of the DUV-LED with the S-EBL and G-EBL.

(a) Schematic image of the DUV-LED and cross-section TEM image for (b) the DUV-LED structure and (c) the AlGaN/AlGaN MQWs, respectively.



The simulation showed that the injection efficiencies for the DUV-LEDs with the S-EBL (single EBL), GEBL (graded EBL), and GSL-EBL (graded superlattice EBL) were 37%, 82%, and 88% through simulation, respectively.

The EL results demonstrated a considerable improvement in the optical properties of the DUV-LED with the GSL-EBL. The optical power of this DUV-LED was approximately 17 times than that of the DUV-LED with the S-EBL at 80 mA.

2018

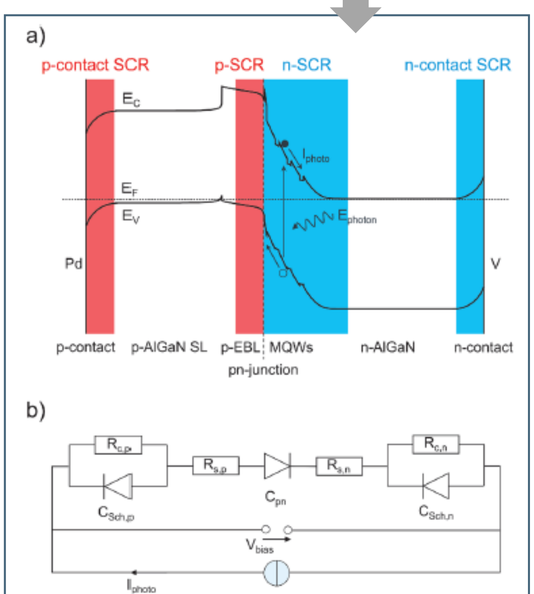
Degradation effects of the active region in UV-C LEDs

JOURNAL OF APPLIED PHYSICS 123, 104502 (2018)

Degradation effects of the active region in UV-C light-emitting diodes

Johannes Glaab,[1,a)] Joscha Haefke,[1] Jan Ruschel,[1] Moritz Brendel,[1] Jens Rass,[1] Tim Kolbe,[1] Arne Knauer,[1] Markus Weyers,[1] Sven Einfeldt,[1] Martin Guttmann,[2] Christian Kuhn,[2] Johannes Enslin,[2] Tim Wernicke,[2] and Michael Kneissl[1,2]
[1]*Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany*
[2]*Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, EW 6-1, 10623 Berlin, Germany*

(a) Schematic of the band diagram of the studied 265nm UV-C LED with space-charge regions at the metal to semiconductor contacts and the pn-junction. The mechanism of band-to-band photocurrent generation in the pn-junction is illustrated. (b) Simplified equivalent circuit of the corresponding LED structure.

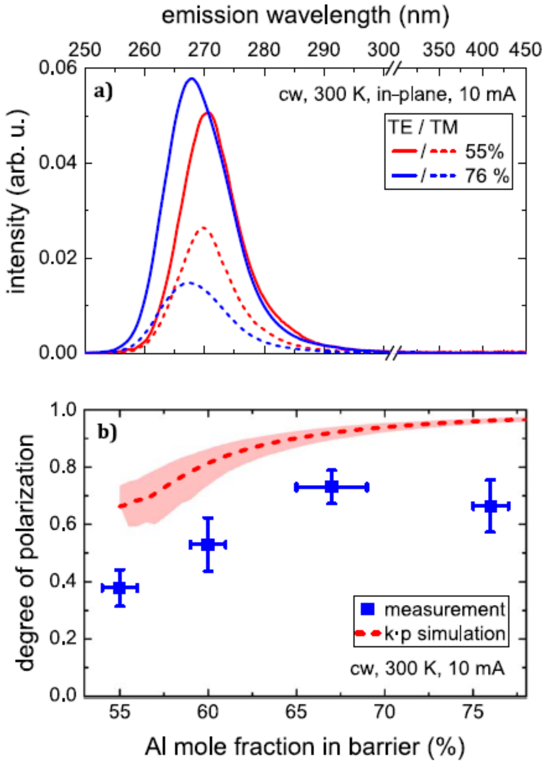


The degradation effects of AlGaN-based UV-C LEDs emitting at ~262 nm under constant current and temperature operation have been investigated by using PCS and C-V measurements. The optical power of the LEDs reduces rapidly over 250 h of operation to about 58% of its initial value. The reduction of the optical power is accompanied by a reduction of the capacitance and an increase in drive voltage of the device.

Furthermore, two changes can be observed in the photocurrent spectrum: First, the photocurrent generated in the QBs, i.e., at 5.25 eV increases, and second, a broad spectral feature emerges between 3.8 eV and 4.5 eV, i.e., energetically below the contributions of QBs and QWs. The increased photocurrent related to the QBs, the reduced capacitance, and the increased drive voltage can be attributed to a reduction of charge states in the n-side of the pn-SCR, most likely by increased defect-induced compensating acceptor states.

2018

Electro-optical properties of AlGaN-based UVC LEDs



(a) Typical in-plane transverse electrical (TE) and transverse magnetic (TM) polarized emission spectra of LEDs with an Al mole fraction in the $Al_xGa_{1-x}N$ QB of x=55% and 76%. (b) Measured degree of polarization (blue boxes) and simulated polarization (red dashed line) as a function of the Al mole fraction in the QB.

IOP Publishing — Semiconductor Science and Technology

Semicond. Sci. Technol. **34** (2019) 085007 (6pp) — https://doi.org/10.1088/1361-6641/ab2c1a

Effect of quantum barrier composition on electro-optical properties of AlGaN-based UVC light emitting diodes

Martin Guttmann[1], Jakob Höpfner[1], Christoph Reich[1], Luca Sulmoni[1], Christian Kuhn[1], Pascal Röder[1], Tim Wernicke[1] and Michael Kneissl[1,2]

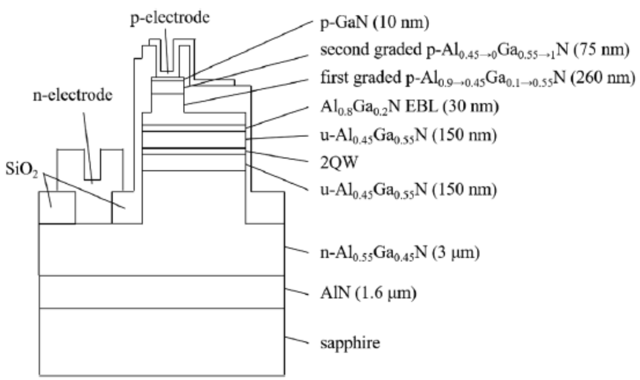
[1] Institute of Solid State Physics, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

[2] Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

The influence of the Al mole fraction in the QB on the emission wavelength, optical polarization, and light output power of AlGaN-based UV LEDs emitting around 270 nm was investigated. LEDs with an Al mole fraction in the QB between 55% and 76% exhibited single peak and dominantly TE polarized emission. The emission wavelength decreases and the fraction of TE polarized light emission increases with increasing Al mole fraction in the QB. Furthermore, the on-wafer emission power increases by a factor of four from 0.2mW at 55% to 0.84mW at 67% Al mole fraction in the QB.

2019

UVB LD with Al composition-graded p-AlGaN cladding layer



Structure of the UVB device

Light confinement and high current density in UVB laser diode structure using Al composition-graded p-AlGaN cladding layer

Cite as: Appl. Phys. Lett. **114**, 191103 (2019); doi: 10.1063/1.5095149
Submitted: 7 March 2019 · Accepted: 25 April 2019 ·
Published Online: 16 May 2019

View Online Export Citation CrossMark

Kosuke Sato,[1,2,a)] Shinji Yasue,[2] Yuya Ogino,[2] Shunya Tanaka,[2] Motoaki Iwaya,[2] Tetsuya Takeuchi,[2] Satoshi Kamiyama,[2] and Isamu Akasaki[2,3]

AFFILIATIONS

[1]Asahi-Kasei Corporation, Fuji, Shizuoka 416-8501, Japan
[2]Faculty of Science and Technology, Meijo University, Nagoya 468-8502, Japan
[3]Akasaki Research Center, Nagoya University, Nagoya 464-8603, Japan

A 260-nm thick graded p-$Al_{0.9\to 0.45}Ga_{0.1\to 0.55}N$ cladding layer with an average AlN mole fraction of 0.68 was designed for a UVB laser diode structure, which exhibited a calculated light confinement factor of 3.5%. Proper light confinement with the cladding layer was confirmed through photoexcited laser oscillation.

The maximum current density measured under the pulse operation reached 41.2 kA/cm2; this is the highest value ever reported. A compositional graded p-AlGaN layer possessing a relatively high AlN mole fraction is promising for both light confinement and high current injection in UVB or UVC devices. By preventing the waveguide emission via the proper design of the active region, a current-injected UVB laser diode will be realized in the future.

2019

UVB LD with Al composition-graded p-AlGaN cladding layer

MICROSCOPY

Microscopy, 2019, 1–10
doi: 10.1093/jmicro/dfz037

Article

Visualization of different carrier concentrations in *n*-type-GaN semiconductors by phase-shifting electron holography with multiple electron biprisms

Kazuo Yamamoto[1,*], Kiyotaka Nakano[1], Atsushi Tanaka[2], Yoshio Honda[2], Yuto Ando[3], Masaya Ogura[3], Miko Matsumoto[1], Satoshi Anada[1], Yukari Ishikawa[2,4], Hiroshi Amano[2,5] and Tsukasa Hirayama[1,2]

[1]Nanostructures Research Laboratory, Japan Fine Ceramics Center, 2-4-1 Mutsuno, Atsuta-ku, Nagoya, Aichi 456-8587, Japan, [2]Institute of Materials and Systems for Sustainability, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan, [3]Department of Electronics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan, [4]Materials Research and Development Laboratory, Japan Fine Ceramics Center, 2-4-1 Mutsuno, Atsuta-ku, Nagoya, Aichi 456-8587, Japan, and [5]Akasaki Research Center, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan

Phase-shifting electron holography (PS-EH) using a transmission electron microscope (TEM) was applied to visualize layers with different concentrations of carriers activated by Si (at dopant levels of 10^{19}, 10^{18}, 10^{17} and 10^{16} atoms cm^{-3}) in n-type GaN semiconductors. To precisely measure the reconstructed phase profiles in the GaN sample, three electron biprisms were used to obtain a series of high-contrast holograms without Fresnel fringes generated by a biprism filament, and a cryo-focused-ion-beam (cryo-FIB) was used to prepare a uniform TEM sample with less distortion in the wide field of view.

Thicknesses of the active and inactive layers at each dopant level were estimated from the observed phase profile and the simulation of theoretical band structure. Ratio of active-layer thickness to total thickness of the TEM sample significantly decreased as dopant concentration decreased; thus, a thicker TEM sample is necessary to visualize lower carrier concentrations.

2019

N-polar AlGaN-based DUV LEDs

Performance of N-polar AlGaN-based ultraviolet (UV) light-emitting diodes (LEDs) with different Al contents in quantum wells (QWs) and barriers is investigated numerically.

Research Article | Vol. 28, No. 21 / 12 October 2020 / *Optics Express* 30423

Optics EXPRESS

Enhanced performance of N-polar AlGaN-based deep-ultraviolet light-emitting diodes

ZHE ZHUANG, DAISUKE IIDA, AND KAZUHIRO OHKAWA*

Computer, Electrical and Mathematical Sciences and Engineering (CEMSE) Division, King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia

*kazuhiro.ohkawa@kaust.edu.sa

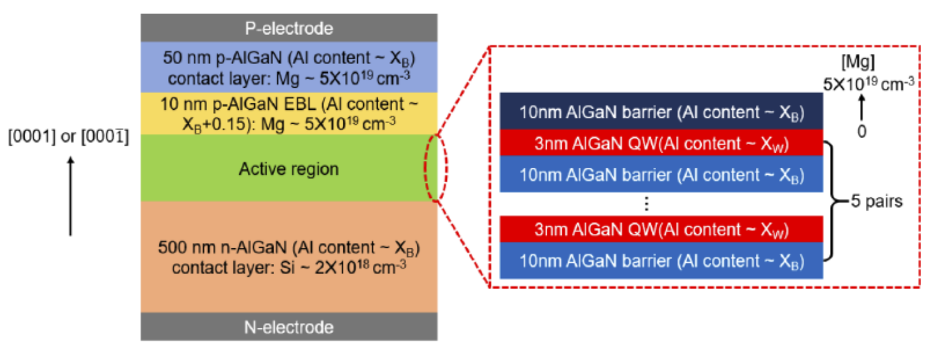
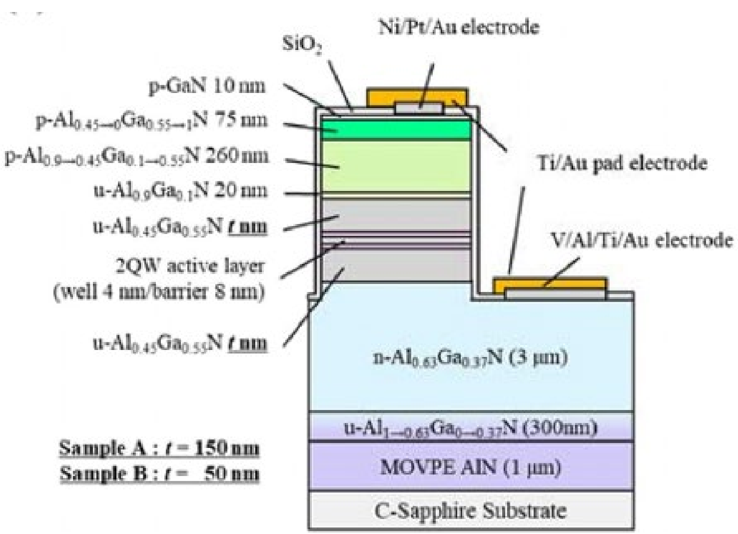


Fig. 1. Schematic of metal-polar [0001] or N-polar [000$\bar{1}$] UV LEDs.

The results show that N-polar structures could improve the maximum IQE and suppress the efficiency droop, especially for DUV LEDs. Compared to metal-polar LEDs, N-polar ones retained higher IQE values even when the acceptor concentrations in the p-layers were one order of magnitude lower. The enhanced performance originated from the higher injection efficiencies of N-polar structures in terms of efficient carrier injection into QWs and suppressed electron overflow at high current densities.

2020

AlGaN-based UV-B laser diode with a high optical confinement fact



Cross sectional image of the base design of the UV-B LD.

AlGaN-based UV-B laser diode with a high optical confinement factor

Cite as: Appl. Phys. Lett. **118**, 163504 (2021); doi: 10.1063/5.0046224
Submitted: 1 February 2021 · Accepted: 6 April 2021 ·
Published Online: 21 April 2021

View Online Export Citation CrossMark

Shunya Tanaka,[1] Yuya Ogino,[1] Kazuki Yamada,[1] Tomoya Omori,[1] Reo Ogura,[1] Shohei Teramura,[1] Moe Shimokawa,[1] Sayaka Ishizuka,[1] Ayumu Yabutani,[1] Sho Iwayama,[1,2] Kosuke Sato,[1,3] Hideto Miyake,[2] Motoaki Iwaya,[1,a)] Tetsuya Takeuchi,[1] Satoshi Kamiyama,[1] and Isamu Akasaki[1,4]

AFFILIATIONS

[1]Faculty of Science and Technology, Meijo University, Nagoya 468-8502, Japan
[2]Graduate School of Regional Innovation Studies, Mie University, Tsu 514-8507, Japan
[3]Asahi-Kasei Corporation, Fuji, Shizuoka 416-8501, Japan
[4]Akasaki Research Center, Nagoya University, Nagoya 464-8603, Japan

To reduce the threshold current density (J_{th}) of ultraviolet (UV)-B AlGaN-based laser diodes, the authors investigated the critical parameters aiming to increase the injection efficiency η_i and the optical confinement factor Γ. Optimization of the thickness of the waveguide layer, the average Al content of the p-type AlGaN cladding layer, and the film thickness of the cladding layer demonstrated that the device characteristics can be improved. This optimization achieved a reduction in J_{th} to 13.3 kA cm^{-2} at a lasing wavelength of 300 nm, thus offering the lowest J_{th} value yet achieved for a UV-B laser diode.

2021

Carrier injection efficiency of AlGaN UV-B laser diodes

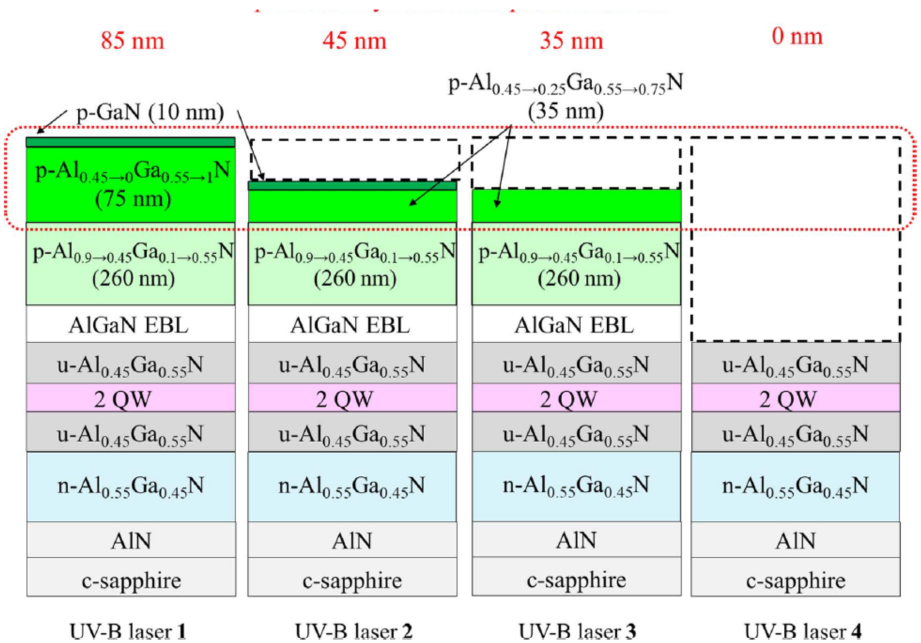
Japanese Journal of Applied Physics **60**, 074002 (2021) **REGULAR PAPER**
https://doi.org/10.35848/1347-4065/ac0643

Check for updates

Analysis of carrier injection efficiency of AlGaN UV-B laser diodes based on the relationship between threshold current density and cavity length

Kosuke Sato[1,2], Tomoya Omori[2], Kazuki Yamada[2], Shunya Tanaka[2], Sayaka Ishizuka[2], Shohei Teramura[2], Sho Iwayama[2,3], Motoaki Iwaya[2], Hideto Miyake[3], Tetsuya Takeuchi[2], Satoshi Kamiyama[2], and Isamu Akasaki[2*†]

[1] *Advanced Devices Technology Center, Asahi Kasei, Fuji, Shizuoka 416-8501, Japan*
[2] *Faculty of Science and Technology, Meijo University, Nagoya, Aichi 468-8502, Japan*
[3] *Graduate School of Regional Innovation Studies, Mie University, Tsu, Mie 514-8507, Japan*



AlGaN film structures of UV-B lasers

To estimate η_i without relying on the unstable output power, the authors analyze in detail how the threshold current density relates to the cavity length. By applying a light confinement factor of 3.5%, an internal loss of 10 cm^{-1}, a current density of 0.56 kA cm^{-2} in the emission layers at zero gain, and a reflectivity of the mirror facet of 0.16, we estimate $\eta_i \approx$ 3.5% for UV-B LDs. This low η_i in UV-B LDs is due to unbalanced injection between electron and hole currents, which leads to electron overflow to the p-GaN side, as indicated by a simulation.

2021