achievement of the optical/electrical lasing in the yellow spectral region. We demonstrate the use of InGaN/GaN violet LD with lasing wavelength λ=401nm (T= 295K) as very efficient resonant pump for an excitation of yellow light from the convertor made of (LuGd)2SiO5 single crystal. Specially grown crystals contain 5% of Sm dopant exhibiting absorption band at 403.1nm. The InGaN laser diode (LD) structure presented in this work was grown by metalorganic vapor phase epitaxy (MOVPE) on GaN bulk substrate. The structure of measured laser diodes consists of the following layers: highly doped GaN substrate, Al0.08Ga0.92 N:Si bottom cladding layer, 100nm GaN:Si guiding layer, and 40nm In0.02Ga0.98N current injection layer, active area: three 3.5nm In0.1Ga0.9N QWs and 9nm In0.02Ga0.98N:Si quantum barriers, 10nm GaN, 30 nm Al0.2Ga0.8N:Mg electron blocking layer, 150nm p-GaN guiding layer, 430nm Al0.08Ga0.92 N:Mg p-cladding, and 30nm GaN:Mg subcontact layer. The devices were fabricated as ridge-waveguide index guided laser diodes with 3μm wide mesa. Tuning the excitation wavelength of the applied LDs was achieved by a precise temperature variation of the laser package (between 25 to 40°C). The increase in the optical power of the LD (keeping the constant emission wavelength) requires increasing laser current with the corresponding decrease of the laser temperature. As a response to the applied excitation we observe several very narrow emission lines with the highest intensity at λ=600.25 nm. Intensity of this emission line increases strongly with LD emitted power (up to 60 mW) showing a potential for demonstration of the optical lasing at this wavelength. Acknowledgement. This research was supported by the National Science Center of Poland within the project DEC-2011/01/B/ST7/06166. [1] M. A. Haase, J. Xie, T. A. Ballen, J. Zhang, B. Hao, Z. H. Yang, T. J. Miller, X. Sun, T. L. Smith, and C. A. Leatherdale, Appl. Phys. Lett., 96, 231116 (2010). [2] Dario Schiavon, Michael Binder, Andreas Loeffler, and Matthias Peter, Appl. Phys. Lett. 102, 113509 (2013).

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Numerical Study on the Optimization of a GaN-Based Dual Color Light-Emitting Diode with P-Type Insertion Layer for Balancing Two-Color Intensities. Shu-Ting Yeh[1], Kai-Lun Chi[2], Jin-Wei Shi[2] and Yuh-Renn Wu[1]; [1]Institute of Photonics and Optoelectronics and Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan; [2]Department of Electrical Engineering, National Central University, Taoyuan, Taiwan.

GaN based Light-Emitting-Diodes (LEDs) with the mixture of red and yellow phosphors are the popular way in fabricating commercial white-light LEDs. However, the limited lifetime of phosphors in white-light LEDs degrades the device efficiency during the processes of optical pumping and re-emission. Therefore, a single-chip, InGaN/GaN based multiple-quantum-wells (MQWs) LEDs with dual center wavelengths composing of different indium compositions on a wafer become an alternative choice. All-InGaN two-color LEDs for blue/green emissions have already been fabricated [1]. However, due to the poor hole transport, the non-uniform distribution of hole inside the MQWs active layers would lead to the unbalanced intensities emission between the dual wavelength unless under a very high bias current density. Therefore, we demonstrated that by inserting an additional p-type GaN layer with proper p-type doping density and thickness between the dual-color QWs, the more balanced dual-color LED structure becomes feasible [2]. This structure could result a more uniform hole distribution inside active layers, which would greatly enhance the output light intensity from n-side MQWs. In this work, we first tried to model the experimental result published in Ref. [2] with our 2D finite difference Poisson and drift-diffusion solver. A new model considering the Indium fluctuation in studying the carrier transport and droop effect[3] in the MQWs active layers has also been included in our simulation to make the fitting and prediction mode accurate. To investigate the influences of p-type doping layer, different doping density and layer thickness were tested. Our result has verified the physics of the experimental data. The result shows that a low p-type doping insertion layer can reach a balanced output light intensity between the two-color wavelengths from small current density to high current density. The InGaN layer quality after inserting p-layer might also be an important factor to affect the balanced light output. Therefore, there exists different condition for device optimization and we will discuss these factors in this paper. References [1]. C.-F. Lu, D.-M. Yeh, H.-S. Chen, C.-F. Huang, J.-J. Huang, and C.-C. Yang, "Junction temperature-controlled spectrum in a two-color InGaN-GaN quantum-well light-emitting diode," Photonics Technology Letters, IEEE, vol. 18, no. 24, pp. 2671–2673, Dec.15, 2006. [2]. Kai-Lun Chi, Shu-Ting Yeh, Yu-Hsiang Yeh, Kun-Yan Lin, Jin-Wei Shi, Yuh-Renn Wu, and Jinn-Kong Sheu, "GaN-Based Dual Color LEDs with P-Type Insertion Layer for Balancing Two-Color Intensities", CLEO 2013 June, San Jose, U.S. [3]. Yuh-Renn Wu, Ravi Shivaraman, Kuang-Chung Wang, and James S. Speck, "Analyzing the physical properties of InGaN multiple quantum well light emitting diodes from nano scale structure", Applied Physics Letter, 101, 083505, 2012.

BP2.42

A Simple Method to Model Bragg Reflectors with Transient Layers Formed at the Interfaces. Zarko Gacevic[1], Nenad Vukmirovic[2] and Enrique Calleja[1]; [1]ISOM, Universidad Politécnica de Madrid, Madrid, Spain; [2]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, 11080 Belgrade, Serbia.

Employment of two in-plane lattice-mismatched semiconductor materials for distributed Bragg reflectors (DBRs), gives rise to strain accumulation at the interfaces. To reduce the interface energy, the constituent quarter-wave layers often undergo intermixing, forming transient layers (TLs). The nominal standard (two-layer period) DBR thus evolves into a quasi three-layer or four-layer period structure [1-3]. In this work, we show that, from the point of view of optical properties, the formation of TLs is equivalent to the decrease in refractive index contrast between the quarter-wave layers of the nominal structure. This implies that a DBR with TLs can be approximated with a corresponding standard DBR [4]. We explain how to find the effective refractive index contrast of the newly-formed structure, in two particular cases: (a) DBRs with homogeneous TLs [1,3] and (b) DBRs with linearly graded TLs [2]. We, consequently, derive simple analytical formulas that precisely quantify the optical properties of this type of structure. The formulas give a rapid insight into those properties that are relevant for optoelectronic engineering. They simplify drastically an optical design that considers DBRs with TLs. We check the accuracy of the suggested method (reduced refractive index contrast approximation, RRICA) by comparison with the traditionally used transfer matrix method (TMM) and demonstrate explicitly that the intermixing does not affect the DBR targeted wavelength, but reduces both the peak reflectivity and the stopband width. Finally, we show that the RRICA modeling yields excellent agreement with experimental reflectivity measurements performed on AlN/GaN Bragg mirrors with nearly homogeneous (Al,Ga)N TLs [3]. The reference samples were grown by molecular beam epitaxy and targeted for violet-blue applications. References: [1] X.L. Ji et al "Structural characterization of (Al,Ga)N/AlN Bragg reflector grown by metalorganic chemical vapor deposition", Phys. Stat. Sol. (a) 205, 1572 (2008). [2] K. Yagi, et al, "Crack-Free AlN/GaN Distributed Bragg Reflectors on AlN Templates", Jap. J. Appl. Phys. 51, 051001 (2012). [3] Z. Gačević et al, "Insight into high-reflectivity AlN/GaN Bragg reflectors with spontaneously formed (Al,Ga)N transient layers at the interfaces", submitted to J. Appl. Phys. [4] Z. Gačević et al, "A simple method to model Bragg reflectors with transient layers formed at the interfaces", submitted to J. Appl. Phys.

BP2.43

The Structure of Polar, Nonpolar, and Semipolar InGaN Quantum Wells Characterized by Atom Probe Tomography. James R. Riley[1], Theeradetch Detchprohm[2], Christian Wetzel[2] and Lincoln Lauhon[1]; [1]Materials Science and Engineering, Northwestern University, Evanston, Illinois; [2]Smart Lighting Research Center, Future Chips Constellation, Department of Physics, Applied Physics, and Astronomy, Rensselaer Polytechnic Institute, Troy, New York.

The ternary alloy InxGa1-xN is an appealing material for the creation of the quantum wells (QWs) that serve as the active regions of visible light-emitting diodes (LEDs) due to its high light-emission efficiency and tunable bandgap. However, QWs grown on the (0001) polar surface of GaN suffer from the quantum-confined Stark effect (QCSE), in which separation of the electron and hole wave functions decreases light-emission efficiency. As In concentration increases the problem is amplified. QWs grown on nonpolar and semipolar surfaces exhibit a reduced QCSE and enable improved performance at longer wavelengths. We have examined the influence of surface polarity on the distribution of In within InGaN QWs in order to better understand the structural characteristics that limit device performance. Atom probe tomography (APT) was performed with a Cameca LEAP4000x on planar InGaN QWs for LED samples grown on (0001) polar, (10-10) nonpolar, and (20-2-1) semipolar surfaces.[1] The end form of the APT samples under analysis is approximately hemispherical and therefore a single specimen presents surfaces of different polarity. It is crucial to understand how these different surfaces influence atom evaporation in order to achieve reliable analysis. In general, Ga and N atoms were collected in the correct 1:1 stoichiometric ratio for N-polar surfaces, whereas a N deficit was observed for Ga-polar surfaces. An explanation for the non-ideal evaporation behavior of N was established previously.[2] Furthermore, in regions of either Ga- or N-polarity the detection probability of group-III species decreased when analysis transitioned into InGaN QWs. This behavior is attributed to additional uncorrelated DC evaporation of these species associated with an increased surface electric field. Regardless, it was found that the group-III mole fraction did not depend on polarity, likely because Ga and In ions exhibit similar evaporation behaviors. This conclusion enables a reliable analysis of In distribution within the QWs and comparison with