TE Polarized MIR Intraband Photodetection in Self Assembled GaN/AlN Quantum Dots

A. Vardi, G. Bahir, F. Guillot, E. Monroy, M. Tchernycheva, F. H. Julien and S. E. Schacham

***Abstract*— In this work we report on Mid-infrared (MIR) in-plane (TE) polarized intraband photocurrent (PC) measurements in GaN/AlN based quantum dots (QDs) structures. Using lateral photodetector configuration the s (TE) polarized front illumination PC signal, at 12 K, peaks at wavelengths from 5.4 μm (0.23 eV) to 7.8 μm (0.16 eV) depending on the dot dimensions.**

***Index Terms*—AlN, GaN, intraband transition, photo-current, mid-infrared, polarization, quantum dots, hopping.**

Samples consist of 20 periods of Si-doped GaN QD layers separated by 3-nm thick AlN barriers, grown by plasma-assisted molecular-beam epitaxy on 1-μm-thick AlN buffer layers on c-sapphire substrates. Self-assembled dots are formed by deposition of 4 monolayers of GaN on AlN surface under nitrogen-rich conditions, following the Stranski-Krastanov growth mode [1]. Atomic force microscopy was used to determine the QD density (1×10^{12} cm^{-2}), average height (1.2 ± 0.5nm), and average diameter (15 ± 3nm). Standard techniques were used to define a novel interdigitated contact structure in which the metallization fingers fill the trench down to the AlN buffer [2]. Two samples (645, 697) with different dot dimensions were studied. Photoluminescence (PL) and Fourier transform infrared (FTIR) spectroscopy were used to investigate the optical properties at room and low temperatures. The substrate was polished at 45° to enable irradiation at both s (TE) and p (TM) configurations, allowing for analysis of polarization effects.

Manuscript received March 15, 2007. This work was supported in part by the U.S – Israel Bi-national Science Foundation under contract No. 2004366.

A. Vardi and G. Bahir are with the Department of Electrical Engineering, Technion-Israel Institute of Technology, Haifa 32000 Israel (phone: 972-4-8293598; fax: 972-4-8235107, e-mail: bahir@ee.technion.ac.il).

F. Guillot, E. Monroy are with the Equipe Mixte CEA-CNRS-UJF Nanophysique et Semiconducteurs, DRFMC/SP2M/PSC, CEA-Grenoble, 17 rue des Martyrs, 38054 Grenoble cedex 9, France (e-mail: eva.monroy@cea.fr).

Tchernycheva, F. H. Julien are with the Action OptoGaN, Institut d'Electronique Fondamentale, UMR 8622 CNRS, Université Paris-Sud, 91405 Orsay cedex, France (e-mail : juju@ief.u-psud.fr).

S. E. Schacham is with the Electrical and Electronic Engineering, College of Judea and Samaria, Ariel 44837, Israel (e-mail: schacham@ee.technion.ac.il).

At room temperature, the PL peaked at 3.6 eV and 3.82 eV for 697 and 645 respectively, due to the difference in dot dimensions. The intraband photocurrent was measured with FTIR spectrometer at room temperature and at low temperature of 12 K. The photocurrent at room temperature is only observed for p polarized light following the intraband s-p_z selections rules of intraband absorption [1, 2]. The low temperature NIR PC, shown in Fig. 1, peaked at 0.74 eV and 0.83 eV for samples 697 and 645 respectively.

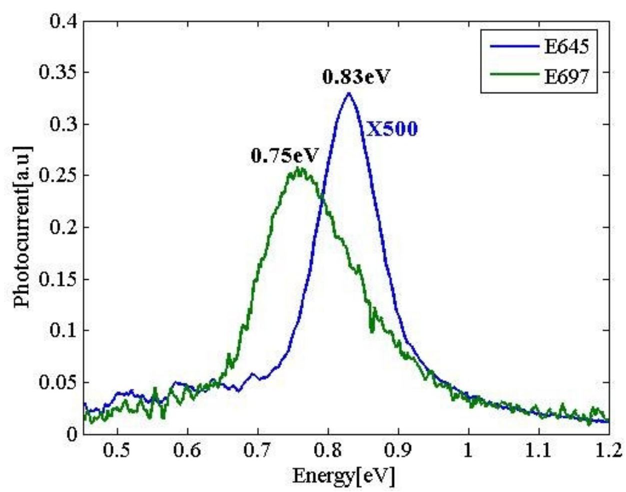

Fig1. Low temperature, p polarized, quantum dot infrared photodetector (QDIP) NIR photoconductive spectra.

Additional s polarized MIR peaks are observed only at 12 K in front (Figure 2) and wedge illumination (Fig. 3). The low energy peak of the MIR spectra in wedge illumination is filtered by the sapphire substrate cut off at 0.23 eV. In addition, Fig.3 shows the polarization dependence of the MIR peak intensity and demonstrates clear s polarization. The fact that the MIR PC obeys the selection rules for absorption from the ground state to the in-plane p_x , p_y excited states and the peak dependence on average dot size are clear evidence that the PC originates from the intraband transition in the nitride QDs. While the near IR, p polarized, PC is generated by the transfer of photo-excited electrons from the p_z state to the wetting layer [2], we propose that the MIR PC is related to deep transition s - p_x or s – p_y in the QDs followed by hopping conduction between localized quantum dot states [3]. 3D simulation and further investigation of the lateral transport mechanism will be presented.

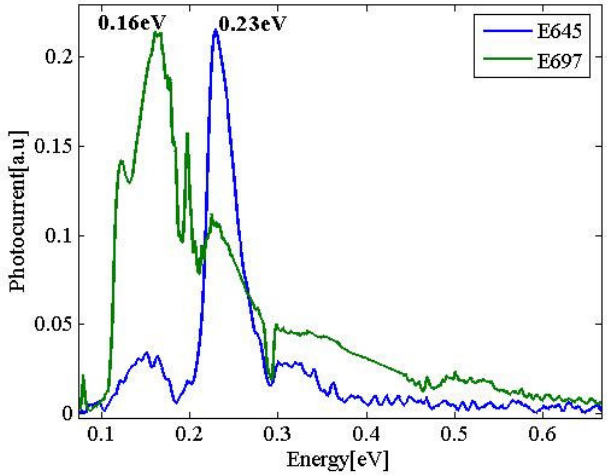

Fig. 2 Low temperature (12 K), front illumination, QDIP MIR spectra.

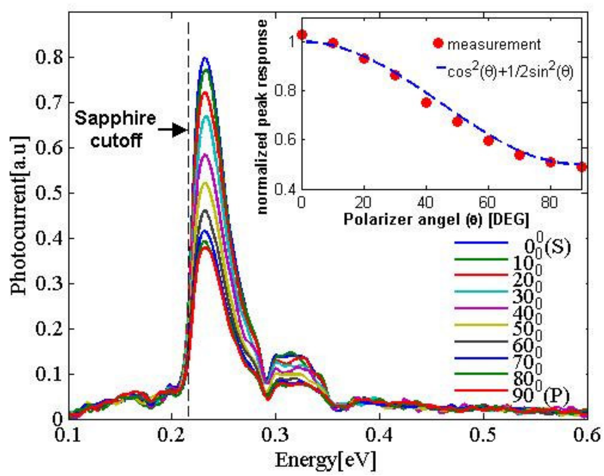

Fig. 3 Measurements of QDIP photocurrent spectra for differnt polarizer angle in wedge configuration. Inset: polarization dependence of the MIR peak intensity.

REFERENCES

[1] F. Guillot et al, “Si-doped GaN/AlN quantum dot superlattices for optoelectronics at telecommunication wavelengths”, J. Appl. Phys. 100, 044326 (2006).

[2] A. Vardi et al., “Room temperature demonstration of GaN/AlN quantum dot intraband infrared photodetector at optical communication wavelength”, Appl. Phys. Lett., 88, 143101 (2006).

[3] H. Z. Song et al, “In-plane photocurrent of self-assembled InGaAs/GaAs (311)B quantum dot arrays”, Phys. Rev. B, 64, 085303 (2001).