Negative Intraband NIR Photoconductivity in GaN/AlN Quantum Dots

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***Abstract*— We have investigated GaN/AlN quantum dot (QD) photodetector relying on an in-plane transport. Negative photoconductivity (PC) is observed when the photodetector is exposed to near infrared (NIR) radiation. The energy and the polarization dependence of the peak correspond to the polarized S to P_z intra-band transition in the QDs, followed by transfer to the WL. The peak magnitude increases exponentially with temperature from 50K to 300K.**

***Index Terms*—AlN, GaN, intraband transition, photo-current, near-infrared, polarization, quantum dots, deep traps.**

Negative photoconductivity (PC) is observed when lateral photodetector based on GaN/AlN quantum dot (QD) is exposed to near infrared (NIR) radiation. The 1.4 µm peak intensity increases exponentially with temperature from 50K to 300K, as seen in Fig. 1. The peak, measured with FTIR using step-scan at fixed frequency, is completely P polarized. PC signal was obtained on single layer of non-intentionally doped dots, even though no absorption is observed.

The measurement was performed on a sample consisting of one GaN QD layer deposited on a c-sapphire substrate covered by 1-µm-thick AlN layer using plasma-assisted molecular-beam epitaxy. QD growth starts by deposition of 2 monolayers of GaN as wetting layer (WL) followed by 2 additional GaN monolayers from which QDs are self-assembled by the Stranski-Krastanov growth mode.

The structure was covered by 3 nm AlN cap. AFM measurements on similar uncapped sample were used to determine the QD density (10^{12} cm^{-2}), average height (1.2±0.5nm), and diameter (15±3 nm) [1]. A lateral photodetector was formed by implementing 2 contacts, 150µm wide and 6µm apart. Rapid- thermal annealing (RTA) was used for the ohmic contacts which consist of a multi-layer metallization of Ti:Al:Ni:Au (15nm:220nm:40nm:300nm). The substrate was polished at 45° to enable irradiation at both S and P configurations, allowing for analysis of polarization effects.

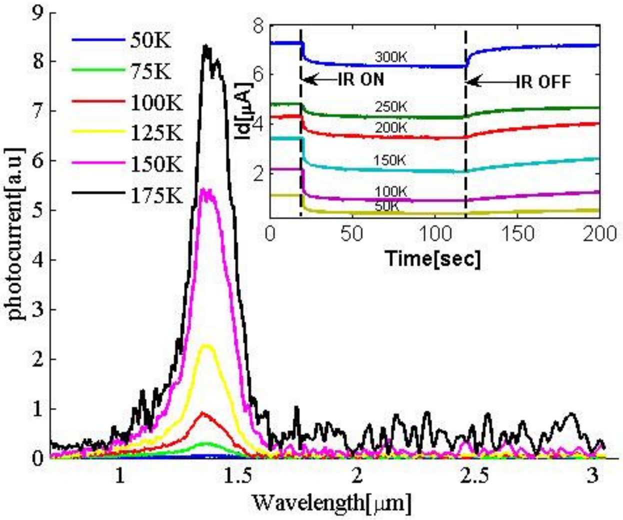

Fig. 1 Intraband photocurrent spectra and (inset) current under 1.55 µm radiation at increasing temperatures for single QDs layer.

Photocurrent experiments were performed by exposing the sample to a 20mW laser radiation at 1.55µm. The current decrease due to the negative PC effect is shown in the inset of Fig. 1. The recovery of the current to its dark value is orders of magnitude faster at 300K than at 50K. The negative response to the NIR radiation is attributed to trapping of carriers which are excited from the QDs to the WL. The energy of the PC peak corresponds to the polarized S to P_z intra-band transition in the QDs, followed by transfer to the WL [2]. From the WL carriers fall into traps which are known to be at high concentration in this material system [3]. The reverse process of re-emission of

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the trapped carriers into the current takes seconds at room temperature but minutes at 50 K.

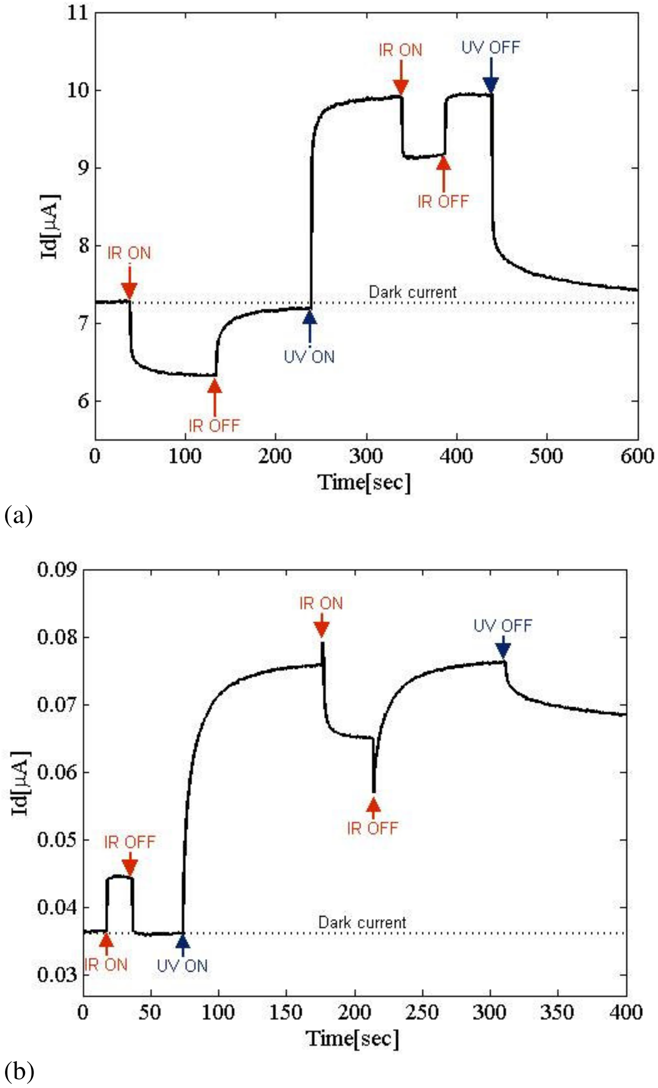

Fig. 2 Current vs. time under IR (1.55 μm) and UV (300 nm) radiation. (a) Room temperature and (b) Low temperature (12 K).

The extremely long time constant results in two opposing findings. On one hand the <u>relative</u> current decrease is much larger at low temperatures. On the other hand, when the PC spectrum is recorded at a relatively high sampling rate, as the temperature is lowered, the very slow response results in an ever decreasing signal. Figure 2 shows the effects of temperature and UV illumination on the sign and time response of the intraband NIR PC. At room temperature the NIR PC is always negative while the UV illumination results in a positive PC due to carrier excitation into the dots and release of trapped carriers from traps in the AlN barriers (Fig 2 A). At low temperature (12 K) the trapping and emission processes are suppressed and <u>the response to NIR radiation becomes positive with very short rise time</u> as shown in Fig. 2 B. UV illumination at low temperature enhances the release of trapped carrier and results in a positive PC effect. Finally, the NIR signal in the presence of UV illumination evolves with time from positive to negative as shown in Fig. 2 B. Further modeling of trapping processes is under study.

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