GaN/ALN NANOSTRUCTURES FOR INTERSUBBAND OPTOELECTRONICS AT TELECOMMUNICATION WAVELENGTHS

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Nitride semiconductors, with a large conduction-band offset (~1.8 eV for GaN/AlN), are promising materials for intersubband (ISB) optoelectronics in the near infrared. To develop nitride ISB devices, the growth of quantum well (QW) and quantum dot (QD) superlattices has to be precisely controlled. In particular, to operate at optical fiber telecommunication wavelengths (1.3 µm, 1.55 µm), QWs and QDs thickness should be reduced to ~1 nm. In this work, we present a study of the growth of GaN/AlN QW and QD infrared photodetectors by plasma-assisted molecular-beam epitaxy.

From the QW superlattice point of view, we have analyzed the effect of Ga and In as a surfactant during growth, as well as the effect of growth interruptions at the AlN/GaN interfaces. Best structural and optical results are obtained on samples grown with Ga as a surfactant during the deposition of both GaN and AlN, leading to an interface roughness at the monolayer scale [1]. On the other hand, Si doping is required in order to populate the first electronic level in the QWs. We have demonstrated that incorporation of Si up to 10^{20} cm^{-3} has no effect on the structural quality of the QW superlattice. From the optical viewpoint, Si doping broadens the emission and absorption spectra and introduces a blue shift due to the screening of the internal electric field. These results are independent on the Si doping location: barrier, QW, or delta doping.

GaN/AlN QW superlattices display *p*-polarized ISB absorption lines that can be tuned in the 1.33-1.91 µm wavelength range by varying the QW thickness from 4 ML to 10 ML [2]. The absorption spectra exhibit Lorentzian shape with a typical FWHM of 70-100 meV in Si doped samples, whereas a line width as small as 40 meV have been measured from undoped samples, which establishes a new state-of-the-art for nitride epitaxial growth. This complete study of the growth of AlN/GaN MQWs for ISB devices has made possible the fabrication of high-performance nitride-based QWIPs operating at 1.4 µm at room temperature [3].

Regarding QD superlattices, we have demonstrated QD densities in the 10^{11} to 10^{12} cm^{-2} range with a height (diameter) around 1-1.5 nm (10-40 nm) depending on the growth conditions (the amount of GaN deposited, the substrate temperature and the growth interruption time after each GaN layer) [4]. No effect of Si-doping on the QD morphology is observed. HRXRD based simulation suggests the superlattices are fully strained on AlN. Strong and narrow (FWHM ~ 70-150 meV) *p*-polarized ISB absorptions peaked at wavelengths ranging in 1.38-1.67 µm are observed at room temperature. These results allowed the fabrication of the first QDIP prototypes operating at telecommunication wavelengths [5].

Financial support by IST FP6 NitWave STREP 004170 program is acknowledged.

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Figures:

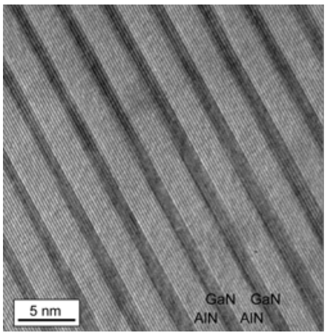

Fig. 1: HRTEM image of the active region of a QWIP structure.

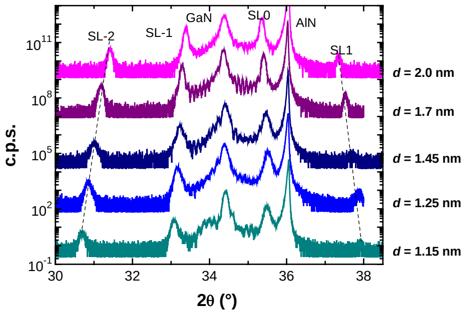

Fig. 2: HRXRD θ–2θ scans of the (0002) reflection of QWIP structures with various QW thicknesses (*d*) in the 1.15-2 nm range.

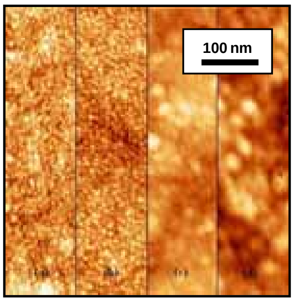

Fig. 3: AFM images of QDs deposited with the following growth interruptions: (a) 0s, (b) 15s, (c) 60s and (d) 120s

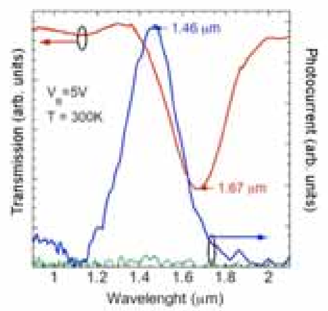

Fig. 4: Room temperature transmission (red line) and photocurrent response (blue line) of a QDIP based on lateral transport.

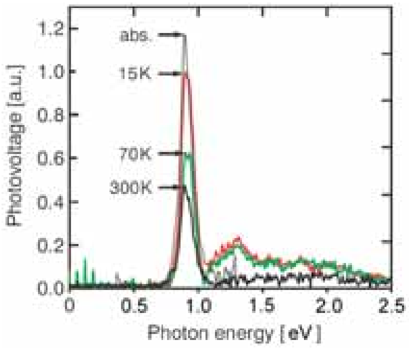

Fig. 5: Temperature-dependent photovoltage measurements from a QWIP, for *p*-polarized light. The absorbance spectrum is shown as dashed line for comparison.