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Unitride
Unioplar Nitride Photonic Devices

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Abstract

We present a review of the latest achievements of the UNITRIDE project in terms of GaN-based quantum engineered photonic devices operating in the near- to far-infrared spectral range.

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Keywords: nitrides; intersubband devices; quantum wells; quantum cascade lasers and detectors; unipolar devices; optoelectronics; telecommunication; infrared

1. Introduction

Semiconductor materials can be made optically active at wavelengths regardless of their band gap by engineering the electron quantum confinement in thin quantum well (QW) or quantum dot (QD) layers. Quantum cascade (QC) lasers or quantum well infrared photodetectors (QWIPs) are well-known illustrations of electron-engineered devices. These control-by-design devices rely on optical intersubband (ISB) transitions between electron-confined states and the desired wavelength of operation can be obtained through a proper choice of the layer thicknesses. Using standard ISB materials such as GaAs/AlGaAs, InGaAs/AlInAs or antimonides, these unipolar devices can be operated from the mid-infrared to the THz spectral range. There is considerable interest in extending the wavelength range of ISB devices to the near-infrared (NIR) spectrum, for which high-power lasers, sensitive room-temperature detectors or ultrafast optical processing devices are highly demanded for numerous appealing applications: telecommunication optoelectronic devices at optical-fiber transmission windows, chemical sensing and pollution detection, industrial process monitoring, night vision, non-invasive medical diagnostics, automotive anti-collision monitoring systems, lidars... However, progress towards short-wavelength ISB devices requires new materials with specific physical properties such as large enough conduction band offsets or remote lateral valleys to accommodate for ISB emission at NIR wavelengths.

Recently, wide-gap III-nitride semiconductors have emerged as excellent candidates for NIR ISB devices. Indeed, the large conduction band offset provided by their heterostructures (1.75 eV for GaN/AlN) offers the potential to push the ISB device operation to the shorter wavelengths of the NIR spectral range, including the 1.3–1.55 μm range used for fibre optics telecommunications. In addition, III-nitrides exhibit extremely short ISB absorption recovery times (∼150–400 fs) due to the strong electron-phonon interaction in these materials, which paves the way for devices operating in the 0.1–1 Tbit/s bit-rate regime. Furthermore, III-nitrides are excellent candidates in view of developing

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NIR unipolar lasers: nonradiative scattering of electrons to the remote lateral valleys is expected to be negligible since these valleys lie very high in energy (>2 eV above the Γ valley), and the wide band gap of nitride semiconductors prevents two-photon absorption in the NIR. Finally, nitride ISB devices provide novel functionalities and superior performance like wavelength tunability, speed, high power handling capabilities, temperature insensitivity and material hardness.

2. Project and achievements

The target of the UNITRIDE project is to develop a new generation of high-performance NIR optoelectronic devices based on the III-nitride semiconductor technology. We will make use of GaN/AlGaN quantum wells or quantum dots and engineer the electronic quantum confinement at a nanometer scales to realize unipolar devices relying on ISB transitions. Our project aims at pushing this family of devices to unprecendently short wavelengths and high-speed operation [1–3]. We concentrate on three key building blocks, namely: quantum cascade detectors, electro-optical phase and amplitude modulators and intersubband lasers either electrically or optically pumped. The latest results of the project are the demonstration of ultrafast quantum cascade detectors at a record short wavelength of 1.5 μm [4], the development of a new generation of electro-optical phase modulators [5] or the demonstration of the first GaN-based THz intersubband devices [6] and observation of reproducible resonant tunnelling in GaN/AlGaN superlattices [7].

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References

[1] M. Tchernycheva, L. Nevou, L. Vivien, F.H. Julien, P.K. Kandaswamy, E. Monroy, et al., GaN/AlGaN nanostructures for intersubband optoelectronics, Phys. Status Solidi (A) 207 (6) (2010) 1421–1424.

[2] M. Tchernycheva, H. Macchadani, L. Nevou, J. Mangeney, L. Vivien, P. Crozat, et al., Intersubband optics in GaN-based nanostructures - physics and applications, Phys. Status Solidi (B) 247 (7) (2010) 1622–1627.

[3] M. Tchernycheva, H. Macchadani, S. Sakr, L. Nevou, J. Mangeney, L. Vivien, et al., Review of nitride infrared intersubband devices, SPIE Proc. Ser. 7602 (2010) 76021A.

[4] S. Sakr, Y. Kotsar, S. Haddadi, M. Tchernycheva, L. Vivien, I. Sarigiannidou, et al., GaN-based quantum cascade photodetectors with 1,5 μm peak detection wavelength, Electron. Lett. 46 (2010) 1685.

[5] H. Machhadani, P.K. Kandaswamy, S. Sakr, A. Vardi, A. Wirtmüller, L. Nevou, et al., GaN/AlGaN intersubband optoelectronic devices, New J Phys 11 (2009) 125023.

[6] H. Machhadani, Y. Kotsar, S. Sakr, M. Tchernycheva, R. Colombelli, J. Mangeney, et al., Terahertz intersubband absorption in GaN/AlGaN step quantum wells, Appl. Phys. Lett. 97 (2010) 191101.

[7] S. Sakr, E. Warde, M. Tchernycheva, F.H. Julien, Ballistic transport in GaN/AlGaN resonant tunneling diodes, J. Appl. Phys. 109 (2011) 023717.