Sb-based interband cascade Mid-IR devices with top GaAs metamorphic layers

Daniel Andres Díaz Thomas, Oleksandr Stepanenko, Michaël Bahriz, Stéphane Calvez, Thomas Batte, Cyril Paranthoen, Eric Tournié, Alexei Baranov, Guilhem Almuneau, Christophe Levallois, et al.

To cite this version:

Daniel Andres Díaz Thomas, Oleksandr Stepanenko, Michaël Bahriz, Stéphane Calvez, Thomas Batte, et al.. Sb-based interband cascade Mid-IR devices with top GaAs metamorphic layers. Compound Semiconductor Week 2021 (CSW 2021), May 2021, Stockholm (online), Sweden. hal-03358749

HAL Id: hal-03358749
https://hal.laas.fr/hal-03358749

Submitted on 29 Sep 2021

Sb-based interband cascade Mid-IR devices with top GaAs metamorphic layers

D.A. Díaz-Thomas[1], O. Stepanenko[2], M. Bahriz[1], S. Calvez[2], T. Batte[3], C. Paranthoen[3], E. Tournié[1],
A. Baranov[1], G. Amuneau[2], C. Levallois[3], and L. Cerutti[1]
[1] IES, Univ. Montpellier, CNRS, F-34000 Montpellier, France
[2] CNRS-LAAS, 7 Avenue du Colonel Roche, F-31400 Toulouse, France
[3] Univ. Rennes, INSA Rennes, CNRS, Institut FOTON – UMR 6082, F-35000 Rennes, France
laurent.cerutti@umontpellier.fr

***Abstract*— We present two different GaSb based interband cascade devices emitting between 3 and 4 µm containing a metamorphic GaAs layer above the active region. The first structure is a Resonant Cavity Light Emitting Diode with an oxidized Al(Ga)As layer whereas the second structure is an Interband Cascade Laser with a GaAs top cladding.**

Keywords—Interband cascade devices; mid-infrared; metamorphic GaAs

GaSb-based Interband Cascaded (IC) devices has become a leading optoelectronic source in the 3-5 µm wavelength range, since laser [1] and efficient light emitting devices [2] have demonstrated continuous wave (CW) operation well above room temperature (RT). These performances pave the way for novel device concepts providing new device functionalities. Despite the growth of effort to improve GaSb processing, the maturity achieved by this technology is still behind the more mature GaAs technology [3] . To address this issue, we explore the potential of using a metamorphic GaAs as the top cladding of Sb-based devices. We present two GaSb based IC devices containing metamorphic GaAs layers grown above the active region.

The first structure is an IC-Resonant Cavity Light Emitting Diodes (RCLED) where an Al(Ga)As layer is inserted to benefit of established AlOx technology for electro-optical confinement. The second one is an ICL emitting at 3.6 µm where the usual AlSb/InAs superlattice (SL) top cladding is replaced by a GaAs layer, besides an easier technological process, the GaAs exhibits a lower thermal resistivity and refractive optical compared with InAs/AlSb SL, which can potentially provide higher device performance.

The RCLED under study is composed of a 14-pairs n-doped AlAsSb/GaSb bottom Bragg mirror, followed by the cavity containing a 7-stages IC active region ending with the GaSb/GaAs interface placed at the first node of the electromagnetic field standing wave after the active region. Close to this interface, a 20 nm thick Al(Ga)As layer dedicated to the AlOx process is inserted before a 1-µm thick GaAs to ensure both efficient carrier spreading and intracavity contact. After processing and oxidation of the structure, a 2-pairs of ZnS/Ge dielectric Bragg mirror with an expected reflectivity within cavity of 91% was deposited. The figure 1 presents the L-I-V curves for structures with 25 µm and 15 µm oxide apertures. The increase of the series resistance with the reduction of the oxide apertures demonstrates efficient electrical confinement. The emission spectrum reveals a narrow electroluminescence peak at 3.26 µm corresponding to the microcavity resonance.

The ICL structure consists of a separate confinement heterostructure (SCH) active region made of a 7 stages IC active gain region designed for emission at 3.6 µm surrounded by an AlSb/InAs bottom superlattices cladding and a top GaAs cladding layer. The structure was processed into 100-µm-wide broad area ridge lasers and cleaved into 2-mm long cavities. The figure 2 shows pulsed the P-I-V (1 µs/1%) at 20°C for this ICL with a GaAs top and for a reference ICL of the same design with an InAs/AlSb top SL cladding layer. The measurements indicate no significant increase in the threshold current density for the ICL with the metamorphic top cladding, measured to be ~ 130 A/cm^2. On the other hand, the slope efficiency drops from 430 mW/A to 390 mW/A when the InAs/AlSb SL is replaced by GaAs. The operating voltage is seen to increase by ~1 V, a feature we tentavely attribute to an unoptimized GaSb/GaAs junction or to an inappropriate choice of the metal contact to the GaAs cladding. As a follow-up of these early measurements, a more complete characterization will be carried-out to determine the internal loss, internal efficiency, temperature dependence and to achieve CW operation.

We will present the complete set of results on the structural (HRXRD, TEM, AFM) and electro-optical-properties of these devices. Nevertheless, these preliminary data open the way to the development of hybrid GaAs/GaSb photonic devices.

Part of this was sponsored by the French "Investment for the Future" program (EquipEx EXTRA, ANR-11-EQPX-0016) and by the French ANR (MIMIC-SEL, ANR-16-CE24-0011). It partially benefited from support of the French RENATECH network and its LAAS and Nanorennes technological facilities.

1. I. Vurgaftman et al., J. of Phys D, 48, 123001 (2015)
2. J. Abell et al., Appl. Phys. Lett. 104, 261103 (2014)
3. C.P. Dietrich et al., Las. & Phot. Rev. 10, 870 (2016)

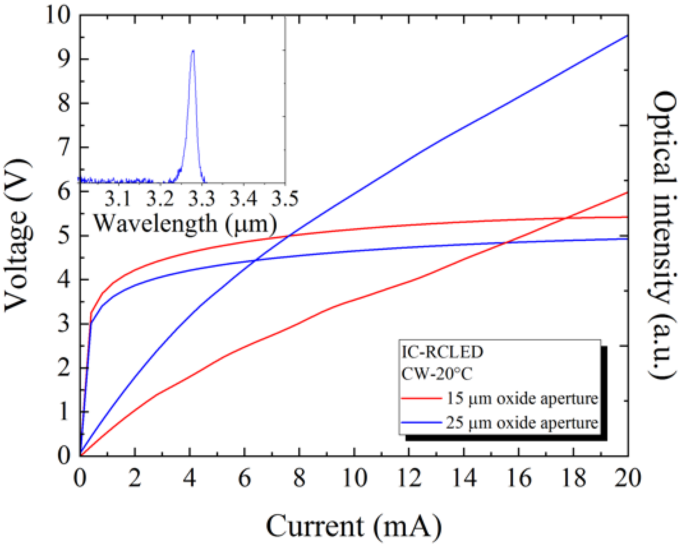

Fig. 1. L-I-V of IC-RCLED in CW at 20°C with AlOx aperture of 15 µm (red) and 25 µm (blue). Insert: Spectrum taken in CW at 20°C of the IC-RCLED with aperture of 25 µm.

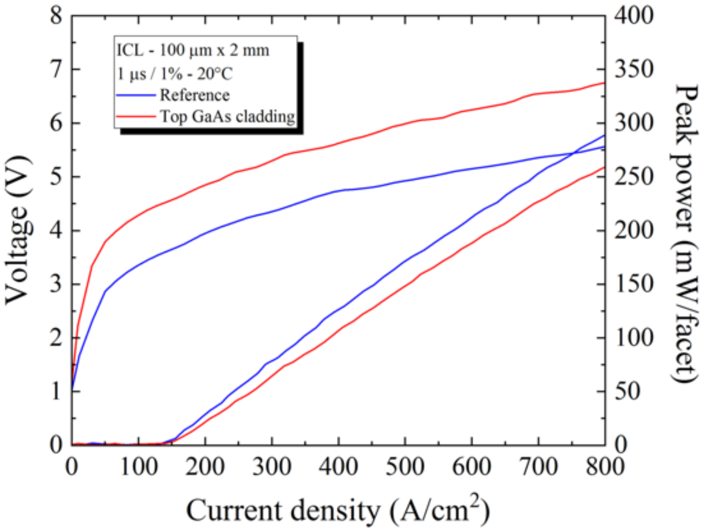

Fig. 2. P-I-V of reference ICL (blue) and ICL with a metamorphic GaAs top cladding (red) taken in pulsed regime at 20°C