Mid-IR laser diodes epitaxially grown by Molecular Beam Epitaxy on silicon substrates

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BIOGRAPHY
Dr Jean-Baptiste Rodriguez is 34 years old; he obtained his PhD from the University of Montpellier in 2005. After a two year post-doctorate at the Center for High Technology Materials (Albuquerque, USA), he was recruited as junior CNRS researcher in the NANOMIR group of the IES in 2008. He has about ten years of experience in the development of ABCS-based optoelectronic devices and study of new epitaxial techniques by MBE. His current interests include the strain relaxation of ABCS on highly mismatched substrates (GaAs and silicon), and developments of InAs/GaSb superlattice infrared photodetectors. He is author or co-author of more than 50 articles in peer-reviewed journal and conference proceedings.

TECHNICAL ABSTRACT
Integration of III-V semiconductor photonic devices with the silicon technology is currently a challenge for the semiconductor industry and research [1]. Indeed, the combination of the III-V semiconductor performances with the well established Si technology would offer new functionalities and new performances in the area of micro/nano-electronic and photonic. The Si technology, which represents the major part of the semiconductor field, offers a large scalability and is very mature, but is limited for light emission due to the Si indirect band gap. On the other hand, III-V semiconductors have interesting properties that can be used for several photonic applications, and also allow fabricating high speed and low consumption transistors. In the last decade, there was an impressive raise of investigations with the goal to unify these two technologies. Two main approaches have been identified to succeed to this very challenging issue. The first one deals with the heterogeneous bonding of III-V semiconductor on Si substrate and several variation of this technique [1]. With this process, high performance laser bonded on SOI has been demonstrated. But this technology lacks the full benefits of the III-V/Si integration. On the other hand, the direct epitaxy of III-V semiconductors onto Si substrate would probably be the best way for large scale integration. But, this approach has proven difficult due to the large mismatches of the lattice constants and of the thermal expansion coefficients, and to the polar/nonpolar character of the III-V/Si interface. This generally results in large densities of threading dislocations [2] and poor device performance.

An exciting approach is the epitaxial growth of Antimony-Based Compounds Semiconductors (ABCS) that include GaSb, AlSb, InAs and their related alloys which can be used in a variety of applications.

The lattice mismatch between ABCS and Si is around 11%. Such a large lattice mismatch generally results in the formation of high threading dislocation densities which are not compatible with the fabrication of high performance devices. However, it was demonstrated that, using ABCS materials under appropriate growth conditions, it is possible to relieve this large strain by the formation of an interfacial 2D array of dislocations [3,4] which greatly reduces the density of threading dislocations. Several publications on the growth of ABCS laser diodes (LD) on highly mismatched substrates such as GaAs [5,6] and Si [7,8] have been reported.

In this communication, we will first present our results on laser grown on Si emitting at 2.3 µm, for spectroscopy applications [9]. We will detail the technological improvement that allowed obtaining CW operation above RT (Figure 1) for Sb-based LD grown onto Si substrate [10].

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Figure 1: CW output-power characteristics of laser diode at 2 µm grown on Si and using the "top-top" contact for different temperatures and the voltage-current curve at 20°C. The inset shows the lasing spectrum of the device under 300 mA, CW and 20°C.

REFERENCES


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