



HAL
open science

Electrical and optical properties of InAs/InSb/GaSb superlattices for mid-infrared applications.

Philippe Christol, Yvan Cuminal, Jean-Baptiste Rodriguez, André Joullié,
V.K. Kononenko, A.A. Afonenko, D.V. Ushakov

► **To cite this version:**

Philippe Christol, Yvan Cuminal, Jean-Baptiste Rodriguez, André Joullié, V.K. Kononenko, et al..
Electrical and optical properties of InAs/InSb/GaSb superlattices for mid-infrared applications.. 14th
International Symposium nanostructures : Physics and Technology., Jun 2006, St Petersburg., Russia.
hal-00103333

HAL Id: hal-00103333

<https://hal.science/hal-00103333>

Submitted on 4 Oct 2006

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Electrical and optical properties of InAs/InSb/GaSb superlattices for mid-infrared applications.

P. Christol¹, Y. Cuminal², J.B. Rodriguez¹, A. Joullié¹, V.K. Kononenko³, A.A. Afonenko⁴ and D.V. Ushakov⁴

¹CEM2-UMR CNRS 5507, Université Montpellier 2, 34095 Montpellier, France

²LASMEA, UMR CNRS 6602, Université Clermont II, 63177 Aubière, France

³Stepanov Institute of Physics NASB, Fr. Scorina Pr., 70, 220072 Minsk, Belarus

⁴Belarussian State University, Fr. Scorina Pr., 4, 220050 Minsk, Belarus

Abstract.

Electrical and optical investigations performed on type-II broken gap InAs/InSb/GaSb superlattices grown on GaSb substrate are reported. Inter-miniband transitions are identified by low temperature (80K) spectra and photoresponse measurements on mesa pin diodes exhibited cut-off wavelength at around 6 μm whatever the temperature between 90K and 290K. Hall measurements have been carried out on 300 periods SL grown on semi-insulating GaAs substrates. The variations versus temperature of carrier concentration and Hall mobility display a change in the type of conductivity of the SL at around 190 K.

Introduction

Binary InAs/GaSb superlattices (SLs) grown on GaSb substrates form an ideal material system for the fabrication of short-period SLs with broken-gap type-II band alignment. They can achieve effective energy gaps that are narrower than that of InAs itself, down to zero. Such narrow gaps are of great interest for the mid- (3-5 μm) and long-wavelength infrared region (8-12 μm) applications, as detectors [1-3], as well as emitters [4-5].

In this communication we report on some electrical and optical characterizations of InAs(N MLs) / InSb(1 ML) / GaSb(N MLs) superlattices suitable for mid-infrared applications.

1. MBE growth of InAs/InSb/GaSb SL

A set of SLs with N = 8, 10, 15 monolayers (MLs) were grown on (100) GaSb by solid source molecular beam epitaxy, using As₂ and Sb₂ valve cracker cells. The growth temperature of the SL was 390°C [6].

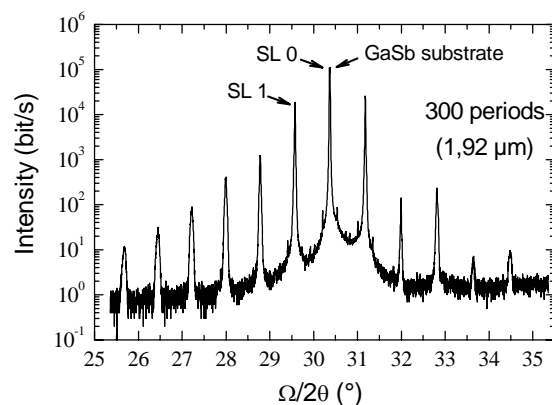


Fig. 1 : HRXRD scan of a 300 periods InAs/InSb/GaSb (10/10) strain compensated SL

The quality of the SLs was strongly improved by inserting into each InAs on GaSb interface one ML of InSb, as it shown in the **Fig. 1** where high resolution X-ray diffraction spectrum of a 300 periods SL structure with total thickness of 1.92 μm is presented. This strain compensation procedure slightly changes the band alignment at the InAs/GaSb interface, inducing a decrease of the fundamental absorption transition C₁-HH₁ between the heavy hole and electron minibands.

2. Optical and electrical properties

For optical transmission measurements, SLs were epitaxied on n-type GaSb substrates, which are much more transparent than p-type ones. Absorption coefficients, deduced from transmission data performed at 80K, are shown in **Fig. 2** for three SLs having a number of N = 8, 10 and 15 MLs. The absorption coefficient is high (e.g. for a SL with N = 10 MLs, $\alpha = 3\,800\text{ cm}^{-1}$ at a wavelength of 5 μm , $5\,500\text{ cm}^{-1}$ at 3 μm) [7]. That means that, in this indirect type II structure, the electron-hole wavefunction overlap is high near the hetero-interfaces. In addition to the C₁-VH₁ transition between fundamental electron and heavy-hole minibands, the other observed excitonic absorption peaks in the spectrum are due to excited inter-miniband transitions C₁-VL₁ and C₁-VH₂ which associate the lowest electron subband (C₁) to the light-hole subband (VL₁) and to the second heavy-hole miniband (VH₂), respectively.

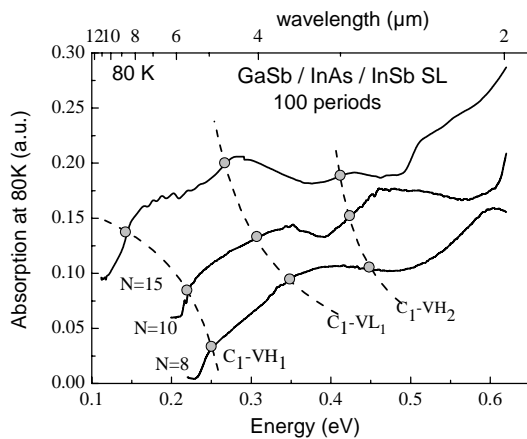


Fig. 2 : Absorption spectra of 100 periods GaSb(N)/InAs(N)/InSb(1) SLs with N = 8, 10, 15 MLs. Circles show the calculated optical transitions while dotted lines are only eye guide.

The photo-response (in current) was studied from mesa pin diodes grown on p-type GaSb substrates. In the case of GaSb(10MLs)/InAs(10MLs)/InSb(1ML) SL structure, an important signal was obtained up to room temperature (**Fig. 3**). We can note that the cut-off wavelength, close to 6μm, is slightly dependent of the temperature, in contrary to the GaSb gap evolution.

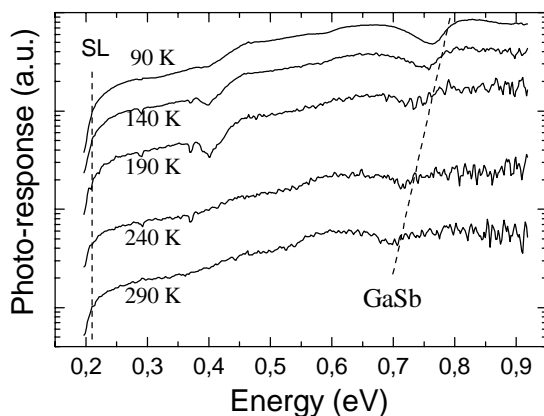


Fig.3 : Spectral responsivity at zero bias of a 250 periods GaSb(10)/InAs(10)/InSb(1) SL at different temperatures.

This peculiarity is a signature of a broken gap type-II band alignment. Electroluminescence was observed on the same pin devices, biased in forward as well as in reverse polarisations.

Resistivity and Hall measurements were carried out on 300 periods SLs grown on (100) semi-insulating GaAs substrates. The Hall voltage linearly varies with

the magnetic field up to 1 Tesla, similarly to a bulk material. Typical variations versus temperature of carrier concentration and Hall mobility are presented **Fig. 4**.

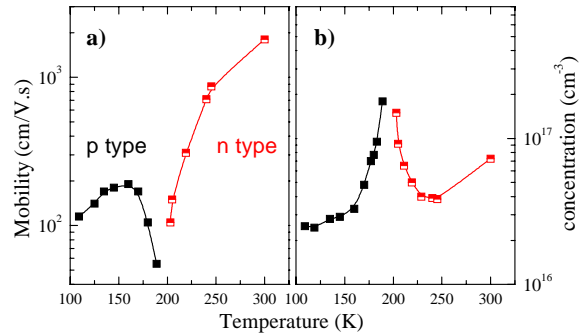


Fig.4 : Carrier mobility (a) and concentration (b) measured under a magnetic field of 0.3 Tesla

A change in the type of conductivity of the SL is observed at around 190 K. The SL is n-type at high temperature, with at 300K a carrier concentration $n = 7 \times 10^{16} \text{cm}^{-3}$ and a mobility of $1800 \text{cm}^2/\text{V.s}$, while is p-type at low temperature, with at 100K a carrier concentration $p = 2.5 \times 10^{16} \text{cm}^{-3}$ and a mobility of $100 \text{cm}^2/\text{V.s}$. This change in conductivity was already reported by other groups, but at lower temperatures (140K [1] and 23K [8]) and can be attributed to the presence of carriers arising from the surface states [9].

Acknowledgment:

This work is partially supported by a cooperation project CNRS/NASB 2005-06 n° 18086. The authors would like to thank S.K. Haywood, Hull University, for low temperature absorption measurements.

References

- [1] A. Rogalski *et al.*, Infrared Phys. Tech. **48**, 39 (2006)
- [2] M. Walther *et al.*, J. Crystal Growth **278**, 156 (2005).
- [3] J.B. Rodriguez *et al.*, Electron. Lett. **41**, 362 (2005)
- [4] A.N. Baranov *et al.*, Appl. Phys. Lett. **71**, 735 (1997).
- [5] D. Hoffman *et al.*, Appl. Phys. Lett. **87**, 201103 (2005).
- [6] J.B. Rodriguez *et al.*, J. Crystal Growth, **274**, 6 (2005).
- [7] J.B. Rodriguez *et al.*, Physica E, **28**, 128 (2005).
- [8] H.J. Haugan *et al.*, J. Crystal Growth **278**, 198 (2005).
- [9] A. Gin *et al.* Appl. Phys. Lett. **84**, 2037 (2004).