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

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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- (3-5µm) and long-wavelength infrared region (8-12µm) 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 As_2 an Sb_2 valve cracker cells. The growth temperature of the SL was 390°C [6].

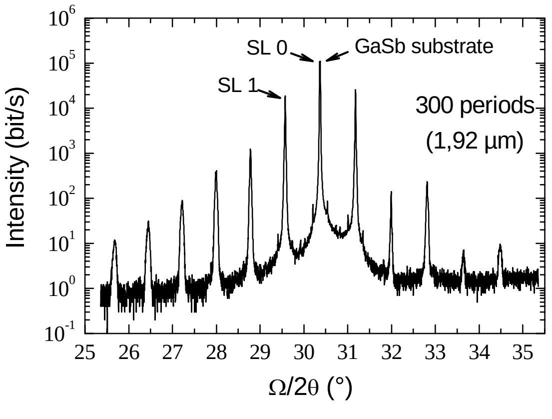

Fig. 1 : HRXRD scan of a 300 periods InAs/InSb/GaSb (10/1/10) strain compensated SL

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, $\alpha = 3\,800\ cm^{-1}$ at a wavelength of 5µm, $5\,500\ cm^{-1}$ at 3µm) [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 C_1-VH_1 transition between fundamental electron and heavy-hole minibands, the other observed excitonic absorption peaks in the spectrum are due to excited inter-miniband transitions C_1-VL_1 and C_1-VH_2 which associate the lowest electron subband (C_1) to the light-hole subband (VL_1) and to the second heavy-hole miniband (VH_2), respectively.

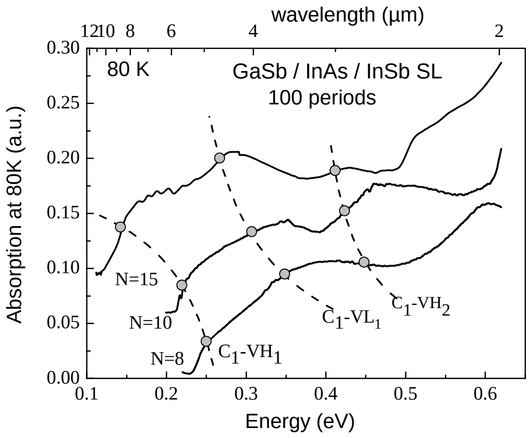

Fig. 2 : Absorption spectra of 100 periods GaSb(N)/InAs(N)/InSb(1) SLs with N = 8, 10, 15 MLs. Circles show the calculated optical transitions while doted lines are only eye guide.

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.

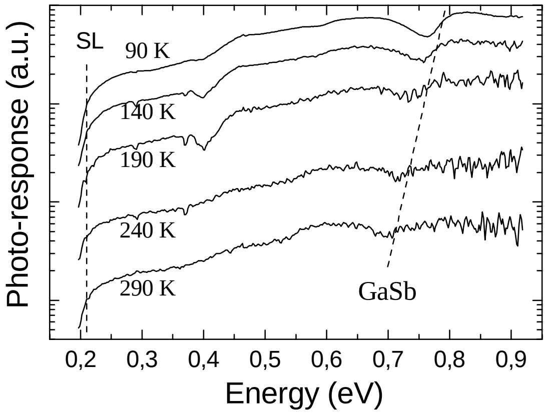

Fig.3 : Spectral responsivity at zero bias of a 250 periods GaSb(10)/InAs(10)/InSb(1) SL at different temperatures.

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**.

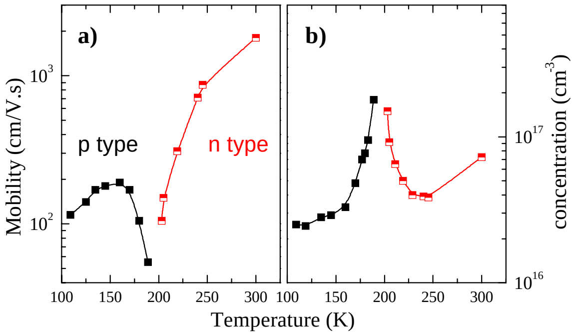

Fig.4 : Carrier mobility (a) and concentration (b) measured under a magnetic filed of 0.3 Tesla

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 = 7x10^{16}cm^{-3} and a mobility of 1800 cm^{2}/V.s, while is p-type at low temperature, with at 100K a carrier concentration p = 2.5x10^{16}cm^{-3} and a mobility of 100 cm²/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].

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