Study of Instrumental Heterostructures Based on Strained InAs/GaSb Superlattices Grown by MOCVD Method

I V Fedorov1,2, R V Levin2, A A Usikova2, N L Bazhenov2, V I Ratushnyi3, B V Pushnyi2 and G G Zegrya1,2

1 Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics, Kronverkskiy pr., 49, lit. A, St. Petersburg 197101, Russia
2 Ioffe Institute, 26 Polytekhnicheskaya, St. Petersburg 194021, Russia
3 Volgodonsk Engineering Technical Institute the Branch of National Research Nuclear Universite “MEPhI”, 73/94 Lenin st., Volgodonsk, Rostovskaya oblast 347360, Russia

E-mail: kingwash@yandex.ru, lev13@yandex.ru

Abstract. This work presents the results of technology development of the growing heterostructures with strained InAs/GaSb superlattice for diode by MOCVD. The InAs/GaSb superlattices consisting of 20 pairs of alternating layers of InAs and GaSb were grown at the temperature of 500°C with similar thickness of the layers. Layer thicknesses were 1 nm, 2 nm and less than 1 nm. Diodes based on these structures were produced by photolithography and etching of meza diodes. The obtained structures were studied by scanning electron microscopy and electroluminescence.

1. Introduction
Optoelectronic devices of the infrared range (IR) are widely used in various fields. The main material system for IR is HgCdTe. Nevertheless, due to some drawbacks of this material system (e.g. HgTe link instability, toxicity of the used materials, etc.) [1], some other material systems are proposed that could replace HgCdTe. Strained InAs/GaSb superlattices are an example of such a material system. For these superlattices lower tunnel currents and Auger-recombination are preferred, which allows to increase the operating temperature of a device based on the given structure [2-3].

2. Experiment
The main aim of this work is to develop a technology of growing heterostructures with strained InAs/GaSb superlattices on GaSb substrates for diode by MOCVD. All the structures were grown with AIXTRON AIX-200. TMIn and TEGa are used as the precursors for group-III elements, while arsine (AsH3) and TMSb are used as the precursors for group-V elements. DETe as a donor and SiH4 as an acceptor were used as a source of alloying impurities. The active area was not doped.

The structures were grown on n-GaSb substrate (001). The emitters were grown at the temperature of 600°C, while the active area was grown at the temperature of 500°C. The pressure in the reactor was 76 Torr. The growth rate was about 1 nm per minute. The carrier gas was purified H2 with the dew point not worse than −100°C, and the total flow through the reactor was 5.5 liters per minute.
The grown structures were studied by CamScan scanning electron microscope and electroluminescence. The growth conditions described in [4] were used for growing of the active area. The pause time for alternating layer was 30 seconds. (Pause is the time when all the flows of TMIn, TEGa, TMSb and arsine are interrupted, except the flow of H₂.)

3. The Results of the Experiment
InAs/GaSb superlattices with different thicknesses of the epitaxial layers were grown. The grown structures consisted of an n-GaSb substrate \((n=(5-7) \cdot 10^{17} \text{ cm}^{-3})\), an n-GaSb:Te buffer layer \((d = 0.5 \mu\text{m}, n=1\cdot10^{18} \text{ cm}^{-3})\), an undoped InAs/GaSb superlattice of 20 periods (with similar thicknesses of quantum well InAs and barrier GaSb with \(d < 1 \text{ nm} \); \(1 \text{ nm} \); \(2 \text{ nm} \) periods thickness is up to \(4 \text{ nm} \)) and a covering p-GaSb:Si layer \((d = 1 \mu\text{m}, p = 1\cdot10^{18} \text{ cm}^{-3})\). Figure 1 shows the scheme of the studied structures with InAs/GaSb superlattice for diode and their energy diagram. We believe, in such structure a minizone is formed for both electrons and holes due to the transparency of the potential barriers. The effective bandgap of this superlattice is the distance between minizones of electrons and holes. This bandgap is smaller than the bandgaps of InAs and GaSb in superlattice. Optical transitions are direct between minizones of electrons and holes.

![Figure 1](image.png)

**Figure 1.** (a) – schematic representation of the studied heterostructures with InAs/GaSb superlattice; (b) – schematic energy diagram of heterostructures.

Diodes were produced by photolithography and etching of meza diodes. Their diameters were \(700 \mu\text{m} \). Ohmic contacts were formed by vacuum deposition of the Cr/Au-Te/Au material system on the substrate of n-GaSb and Cr/Au+Ge/Au on the covering layer of the p-GaSb cap, respectively. The scheme of diodes is shown in Figure 2. The contact on the overlapping p-GaAs layer was shifted relative to the center of the diode to provide the largest surface area for radiation.
The electroluminescence spectra of diodes (Figure 3) was measured at the temperature $T = 77$ K under pulse excitation (frequency 1 kHz, pulse duration 1 μs) with the use of computer-controlled installation employing a grating monochromator and a lock-in amplifier. InSb photodiode was used as a detector. In the range of $0.2 – 0.3$ eV a peak with the maximum $= 0.25$ eV was observed, and it was the same regardless of the size of the superlattice period. The largest peak of luminescence was observed for the sample with superlattice period less than 1 nm. The full-width at half-maximum (FWHM) of the spectrum at $T=77$ K is about 17 meV for all samples studied. It is most likely that this peak is related to InAs/GaSb superlattice radiation. This peak doesn’t correlate with a quaternary solid solution of the GaInAsSb composition which could have been formed, because the solution has the larger band gap. Similar peak is observed in [5], which confirms that this peak is a consequence of the optical transition in the InAs/GaSb superlattice. In the range of $0.45 – 0.9$ eV there was a peak with the maximum $= 0.75$ eV related to the GaSb substrate.
Figure 3. The electroluminescence spectra of diodes with InAs/GaSb superlattices consisting of 20 periods (with similar thicknesses of InAs and GaSb layers $d < 1$ nm; 1 nm; 2 nm) in the range of $0.2 - 0.9$ eV.

As a result, the technology of growing heterostructures with InAs/GaSb superlattices for diode by MOCVD method was developed. Diodes with superlattices of 1, 2 and <1 nm layer thicknesses were produced. Emitting diodes were fabricated from the grown structures and their electroluminescence spectra were studied. Two peaks (with energy 0.25 eV, which is related to the InAs/GaSb superlattice radiation, and with energy 0.75 eV, which is related to the GaSb substrate) were observed in the electroluminescence spectra.

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