Study of Strained Superlattices Grown by MOCVD Method

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Abstract. This study is dedicated to the development of the technology of InAs/GaSb superlattice by MOCVD. There was obtained an InAs/GaSb superlattice consisting of 10 pairs of alternating layers of InAs and GaSb grown at the temperature of 500°C. The obtained structures were studied by transmission electron microscopy (TEM) and photoluminescence (PL). Also, a light-emitting structure with quantum well was obtained to substantiate the developed technology.

Introduction

Human vision is limited by the visible spectrum. Expansion of the boundaries of human vision is possible by creation of devices that operate in short and mid-wavelength IR. For example, night vision goggles enable humans to see in the darkness, and thermal viewer can be used for malfunctions detection in a heating system or in thermal intelligence for military purposes.

Materials that can be used in production of short and mid-wavelength IR devices include strained InAs/GaSb superlattices. The advantages of such a material system as InAs/GaSb are the possibility to reduce tunneling currents, the swift Auger recombination and, as a consequence, the possibility to increase the operating temperature of the device for the given structure [1-2].

Experiment

The main method of InAs/GaSb superlattices growing is the method of molecular beam epitaxy [3]. In this study we showed the possibility of InAs/GaSb superlattices growing by metalorganic chemical vapor deposition (MOCVD), developed the technology of InAs/GaSb superlattice growing by MOCVD and resolved the following objectives: finding the best conditions to grow InAs/GaSb superlattice and examination of the structural and optical-energy characteristics of the structures obtained as the result.

All the structures were grown with AIXTRON AIX-200. Sources of the growth elements were the following compounds: TMIn, TEGa, TMS and AsH$_3$.

The structures were grown on n-GaSb substrate (001) at the temperature of 500°C. The pressure in the reactor was 76 Torr. The substrate rotated at the rate of 100 revolutions 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 litres per minute. The grown structures were studied by transmission electron microscopy (TEM) and photoluminescence (PL).

The Results of the Experiment
The effect of pauses between growth of the individual layers on the sharpness of heterointerface was studied. (Pause is the time when all the flows of TMIn, TEGa, TMSb, AsH₃ are interrupted, except the flow of H₂.) For this study, a structure including 6 pairs of alternating InAs and GaSb layers was grown under the growth temperature of 500°C. The flows of compounds were interrupted after each layer of InAs or GaSb was grown, while the flow of H₂ was still continued for a time period (t). This time period was defined as the result of the following ratio: 

\[ t = \frac{V_p}{G} \]

where \( V_p \) is the volume of the reactor, cm³, and \( G \) is hydrogen flow rate, cm³/sec. The pause time between 2 pairs of the InAs and GaSb layers, when the flowing of the compounds of TEGa and Arsine was stopped, was 1 minute. The pause time for layer switching was: 10 seconds for the first 2 pairs of the InAs and GaSb layers, 30 seconds for the second 2 pairs and 50 seconds for the third 2 pairs.

The results of this study showed that all the InAs/GaSb borders were of equal quality, regardless of the exposure time or the direction of switching (GaSb→InAs or InAs→GaSb). The image of the sample is shown in Figure 1. For the InAs/GaSb superlattices growing, an average pause between alternating layers was chosen, which was 30 seconds.

![Figure 1. TEM image of superlattice including 6 pairs of InAs and GaSb alternating layers. Pause between alternating layers 1 to 4 was 10 seconds, between alternating layers 5 to 8 – 30 seconds, and between alternating layers 9 to 12 – 50 seconds.](image)

The InAs/GaSb superlattice consisting of 10 pairs of alternating InAs and GaSb layers was grown at the temperature of 500°C as the result of finding the best growing conditions. The obtained layers of InAs and GaSb have clearly defined borders and thicknesses on the electron micrograph (Figure 2). The growth rate of InAs was 0.2 nm per sec. The growth rate of GaSb was 0.03 nm per sec. The thickness of the superlattice’s layers varied in the range of 1.4 nm to 1.9 nm for InAs and 2.5 nm to 3.0 nm for GaSb.
Figure 2. TEM image of a superlattice consisting of 10 pairs of alternating InAs and GaSb layers. Pause time between alternating layers was 30 seconds.

The PL spectra of the superlattice of 10 pairs of alternating InAs and GaSb layers was measured at the temperature $T = 77$ K. The pumping source used for the PL measurements was diode laser with the wavelength of $\sim 1 \mu$m. In the range of $0.45-0.9$ eV the superlattice had the following peaks: the maximum $= 0.801$ eV, (this peak is related to interband transition in the GaSb layers) and the maximum $= 0.725$ eV (this peak is related to the GaSb substrate). In the range of $0.27-0.45$ eV the superlattice had a peak with the maximum $= 0.315$ eV and full width at half maximum $= 78$ meV, which is most probably related to the radiative recombination in the InAs/GaSb superlattice layers. Figure 3 shows the PL spectrum for the superlattice of 10 pairs of layers in the energy range of $0.27-0.45$ eV.

A light-emitting structure with quantum well was grown. This structure (Figure 4) consisted of a substrate of $n$-GaSb ($n = 5-7\times10^{17}$ cm$^{-3}$), a buffer layer of $n$-GaSb:Te ($d = 0.5-0.9 \mu$m, $n = 5\times10^{17}$ cm$^{-3}$), an undoped InAs quantum well ($d = 5$ nm) and a capping layer $p$-GaSb:Si ($d = 1 \mu$m, $p = 3-4\times10^{17}$ cm$^{-3}$).
Figure 4. The structure of p-GaSb/InAs/p-GaSb with deep quantum well.

The spectra of electroluminescence (EL) was measured in the spectral range of 2−5 μm depending on the feed current. The samples were placed under a pulse current of a rectangular shape and the frequency of 512 Hz. The amplitude of the current varied in the range ±(0−200 mA). Radiation spectra were measured at 77−300K using a PC controller on the basis of a DK-480 monochromator. For radiation recording, a cooled InSb photodiode (Judson Co) was used. As can be seen from the electroluminescence spectra, the resulting structure has a high emission intensity (Figure 5).

Figure 5. EL spectra of the n-GaSb/n-InAs/p-GaSb structure at different currents in the range of 25−150 mA and T = 77K.

Sublinear dependence of the radiation intensity on the driving current at 77 and 300 K was studied. We suppose that the peak of EL with maximum $\approx 0.41$ eV (77 K) and maximum $\approx 0.37$ eV (300 K) corresponds to the radiative recombination of InAs layer.

The authors thank B. A. Matveev and M. A. Remenniy for their assistance in the research. The work was executed with partial support of the RFBR grant № 16-08-01130-a.

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