The development of technology for growing InAs/GaSb superlattices by MOCVD

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Abstract. This study is dedicated to developing the technology for growing InAs/GaSb superlattices (SLs) by MOCVD. The structures were studied by transmission electron microscopy (TEM) and photoluminescence (PL) methods. We concluded that hetero-interface sharpness is not affected by the pause time between growth stages for separate layers or by switching the layer direction. A possible interpretation for the spectra of SLs was suggested.

1. Introduction

Devices operating in the near-infrared (NIR) and mid-wavelength infrared (MWIR) ranges can be used in various fields, from detection of harmful substances in the atmosphere to military applications. Development and production of such devices is a promising task.

One of the materials that can be used for the creation of photovoltaic converters and light emitting devices for NIR and MWIR is InAs/GaSb SLs. The use of InAs/GaSb SLs in devices makes it possible to reduce tunneling currents and the Auger recombination rate, as well as to increase the operating temperature of devices [1-2]. Molecular beam epitaxy (MBE) is the main technique to grow InAs/GaSb SLs, which is why the majority of published studies are concerned with InAs/GaSb SLs grown by MBE. The paper [3] also deals with the incapacity to grow InAs/GaSb SLs by metal organic chemical vapor deposition (MOCVD). Attempts to create such superlattices were reported in a few articles [4-6]. Follow-ups to these studies have not been published. The aim of this study is to develop the technology for growing InAs/GaSb SLs by MOCVD. The following tasks are an inherent part of this goal: to find the best conditions for growing InAs/GaSb superlattices, and to study the structural and optical-energy characteristics of the grown structures.

2. Experimental details

All the experiments were carried out with an AIXTRON AIX-200 reactor. The structures were grown on n-GaSb (001) substrates at a temperature of 500°C. The pressure in the reactor was 76 Torr. The substrate was rotated at a rate of 100 revolutions per minute. The carrier gas was purified hydrogen with the dew point not worse than −100°C. The total flow through the reactor was 5.5 liters per minute. The sources of elements for growth were the following compounds: TMIn, TEGa, TMSb, and AsH₃. The grown structures were studied by TEM and PL.
3. Results and discussion

The influence of the pause time between superlattice growth stages on the sharpness of heterointerfaces was studied. (Pause time is the time when all flows of TMIn, TEGa, TMSb, and AsH$_3$ are interrupted, except for the flow of H$_2$.) For this purpose, a superlattice consisting of 6 alternating layers of InAs and GaSb was grown (figure 1). The growth of each layer of GaSb started with the TEGa supply, and the growth of each layer of InAs started with the AsH$_3$ supply. The flows of TMIn, TEGa, TMSb and AsH$_3$ were interrupted after each grown layer of InAs or GaSb, but the flow of H$_2$ was continued for a time period ($t$). This time was defined as the following ratio: $t = \frac{V_p}{G}$, where $V_p$ is the volume of the reactor, cm$^3$, and $G$ is the flow rate of hydrogen, cm$^3$/sec.

![Figure 1](image)

Figure 1. TEM image of a superlattice consisting of 6 alternating layers of InAs and GaSb.

The pause time between growing 2 pairs of the layers of InAs and GaSb, when the flowing of the compounds of TEGa and Arsine was stopped, was 1 minute. The exposure time after which the layers were changed was: 10 seconds for the first 2 pairs of InAs and GaSb layers, 30 seconds for the second 2 pairs, and 50 seconds for the third 2 pairs.

The results of this research suggest that all the borders of InAs/GaSb were of equal quality, regardless of the exposure time or the direction of switching (GaSb $\rightarrow$ InAs or InAs $\rightarrow$ GaSb).

The InAs/GaSb superlattices of 5 and 10 pairs of interlacing layers of InAs and GaSb grown at a temperature of 500°C were created after finding the optimal conditions for creating them. The microstructure of the samples was studied by TEM. The obtained layers of InAs and GaSb have clearly defined borders and thicknesses on the electron micrograph (figure 2). The growth rate for InAs was 0.2 nm per sec. The growth rate for GaSb was 0.03 nm per sec. The thickness of 5-pair layers of the superlattice varied in the range of 1.4 nm to 2.0 nm for InAs and of 2.9 nm to 3.1 nm for GaSb. The thickness of 10-pair layers of the superlattice varied in the range of 1.4 nm to 1.9 nm for InAs and of 2.5 nm to 3.0 nm for GaSb.
Figure 2. TEM images of: (a) a superlattice consisting of 5 pairs of alternating layers of InAs and GaSb; (b) a superlattice consisting of 10 pairs of alternating layers of InAs and GaSb.

Photoluminescence measurements for the superlattice of 5 alternating layer pairs at a temperature $T = 77\text{K}$ gave the following results: the superlattice showed a PL intensity maximum at 0.801 eV (this peak is related to the interband transition in GaSb layers) and a maximum at 0.725 eV (this peak is related to the GaSb substrate). The radiation of the superlattice itself was not observed, which is due to the insufficient thickness of 5 pairs of alternating InAs and GaSb layers.

The PL spectra of the superlattice of 10 alternating layer pairs of InAs and GaSb was measured at a temperature $T = 77\text{K}$ in the range of 0.45 to 0.9 eV. They had the same peaks as those of the superlattice of 5 alternating layer pairs. At the same time, the PL spectra differ in the spectral range of 0.27 to 0.55 eV. Figure 3 shows the PL spectra of the superlattice of 10 alternating layer pairs. The peak with a maximum at 0.315 eV and a half-width of 78 meV is most probably related to the energetic transit in InAs/GaSb superlattice layers.

Figure 3. The PL spectra of the superlattice of 10 alternating InAs and GaSb layer pairs.
The result of this research is a development of the technology for the creation of InAs/GaSb superlattices by MOCVD at a temperature of 500°C. The following superlattices were created: the superlattice of 5 alternating InAs and GaSb layer pairs, and the superlattice of 10 alternating InAs and GaSb layer pairs. The resulting structures were examined by PL and TEM. The obtained superlattice had an InAs thickness of 1.4 nm to 2.0 nm and a GaSb thickness of 2.5 nm to 3.1 nm. The peak of the radiation related to the superlattice in the PL spectra at a temperature of 77 K was in the spectral range of 2.4 µm to 3.4 µm.

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