MID-INFRARED LIGHT EMITTING DIODES AND HIGH-SPEED PHOTODIODES BASED ON TYPE II HETEROSTRUCTURES WITH DEEP AlSb/InAsSb/AlSb QUANTUM WELLS IN ACTIVE LAYERS

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We report the first study of positive and negative luminescense in light-emitting diodes (LEDs) and photoelecrtical properties of type II p-InAs/AlSb/InAsSb/AlSb/p(n)-GaSb(InAs) heterostructures with deep single and triple quantum wells (QW) incorporated at the heterointerface. Recently negative electroluminescense (EL) has been studied in the narrow-gap InAs, InSb, CdHgTe, InAsSb bulks, p-n junctions and superlattices [1,2]. The structures were grown on p-InAs: Mn (100) substrate by metal-organic vapor phase epitaxy and consist of 20 nm-AlSb/5 nm-$InAs_{0.84}Sb_{0.16}$/20 nm-AlSb QW and 0.5 μm p(n)-GaSb(InAs) capped layer. Mesa-diodes of 300 μm in diameter were prepared by standard photolithography. EL spectra were measured both at forward and reverse bias at 77 K and in higher temperature range 300-380 K. Low-temperature spectra at the forward bias (“+” is at the p-InAs substrate) consist of two positive EL bands with photon energy $h\nu_{max}$ = 0.407 eV and 0.376 eV (λ_{max} = 3.05 μm and 3.3 μm, respectively), which can be written to band-to-band radiative recombination transitions in InAs and from Mn acceptor level (E_a = 31 meV). Full width at a half maximum (FWHM) was about 21 meV for the both bands. High-intensive negative EL was found in temperature range 300-380 K at the reverse bias. Negative EL spectra were situated in the range 0.3-0.4 eV (3-4 μm) and their shape was similar to ones of positive EL (Fig.1). Dependence of negative EL intensity on drive current value in the range of 25-200 mA, photon energy and temperature was studied. It was established that at high temperature (> 75 °C) and drive current up to 100-150 mA the negative EL intensity exceeds the positive one by 60 %. High efficiency of the negative EL was due to the suppression of Auger recombination at temperature increase.

Proposed heterostructures can operate as LEDs or as photodiodes with switching positive-to-negative luminescense in the spectral range 3-4 μm. Their applications include gas sensing, ecological monitoring, testing of thermal imagers etc.

Last years a great attention have been paid to creation new type QW photodiodes for mid-infrared spectral range. GaAs/AlGaAs and InGaAs/InP QW photodiodes operated in the spectral range 3-5 μm were reported [3]. Recently high-speed photodiodes based on GaSb heterostructures were designed by us [4]. In the frame of this work we studied also electrical and photoelectrical properties of the nanostructures p-InAs/p(n)GaSb(InAs) with a single and triple QWs in active layer which demonstrated high luminescence efficiency. Current-voltage (I-V) characteristics, capacitance-voltage and spectra of photoresponse were first studied at 77 and 300 K for the samples with QW at the interface. Experimental results have shown rectifying I-V characteristics at low bias. The differential resistance R_0 was evaluated from I-V characteristics at zero bias. We found R_0=258 kOhm and $R_0\times A$=120 Ohm×cm^2 (77 K). Fig. 2 demonstrates the spectral response for photodiode based on p-InAs/AlSb/InAsSb/AlSb/p-GaSb single QW heterostructure measured at 77 and 300 K. The spectra are located in the range of 1.0-3.4 μm at 77 K and in the range 1.2-3.8 μm at 300 K. At T=77 K a weak additional peak was observed at around of 4.3 μm. High quantum efficiency η=0.6-0.7 and detectivity $D_\lambda^*=10^{10}$- 3.5×10^{11} cmHz$^{1/2}$W^{-1} at T=200-77 K were evaluated in the photovoltaic mode. Surprising sharp fall of capacitance versus reverse bias was observed in the samples with 3 QWs in an active layer (fig.3). Capacitance decreased from 200 pF (V=0 V) up to 1.5 pF (V=-1 V) at room temperature. It correspond to $\tau=R_LC=75$ ps where $R_L=50$ Ohm. It is evidence that charge depletion layer is situated in the quantum size region of the structure. This value corresponds to high frequency bandwidth about 10 GHz. Such superfast QW photodiodes are suitable for heterodyne detection of quantum cascade lasers, ecological monitoring, medical diagnostics.

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Figures:

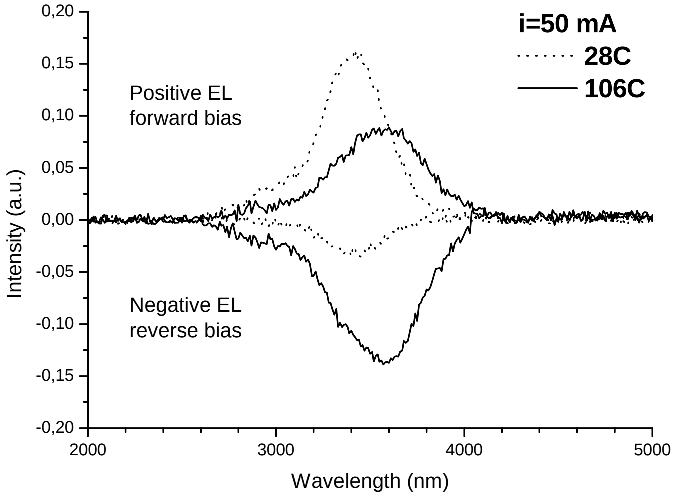
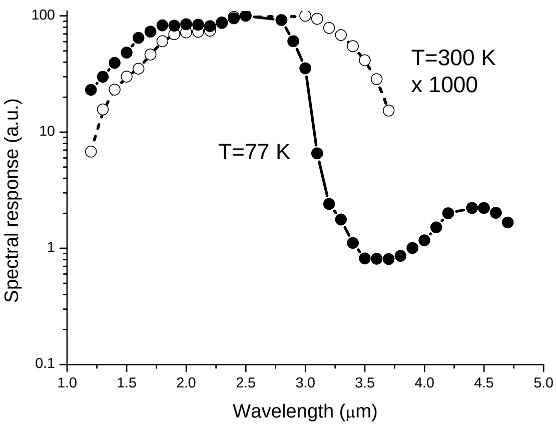


Fig. 1. EL spectra of InAs/AlSb/InAsSb/AlSb/GaSb SQW heterostructure under forward and reverse bias at two temperatures.



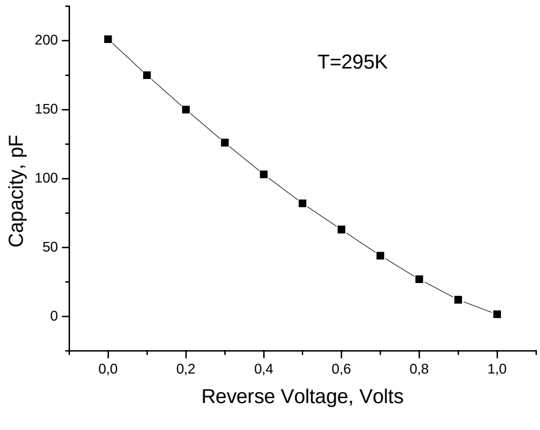


Fig. 2. Normalised spectra of photoresponse of the InAs/

Fig.3. Capacitance versus reverse bias for the

AlSb/InAsSb/AlSb/GaSb single QW heterostructure.

triple AlSb/InAsSb/AlSb QWs heterostructure.