Proceedings of the XXV International School of Semiconducting Compounds, Jaszowiec 1996

OPTICAL PROPERTIES OF $Al_xGa_{1-x}As_ySb_{1-y}$ EPITAXIAL LAYERS

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Photoluminescence spectra of $Al_xGa_{1-x}As_ySb_{1-y}$ layers ($x = 0.2$–0.5, $y = 0.02$–0.03) grown by liquid-phase epitaxy on GaSb substrates were studied in a wide temperature range (14–295 K). The temperature changes of energy and intensity of the layer and substrate emission were measured. Linear part of the temperature-induced energy shift of the $Al_{0.20}Ga_{0.80}As_{0.02}Sb_{0.98}$ band-to-band emission exhibits a slope of −0.3 meV/K and −0.45 meV/K at temperatures 150 K and 295 K, respectively.

PACS numbers: 78.55.Cr, 78.66.Fd

The $Al_xGa_{1-x}As_ySb_{1-y}$ alloys lattice-matched to GaSb have attracted attention as very promising materials for optoelectronic devices, especially for long--path optical fiber communication systems and for application in molecular spectroscopy. There have been reports on the layer growth and the device fabrication (see, e.g., [1–3]); however, the knowledge about radiative recombination processes is relatively poor. In this paper we study photoluminescence properties of $Al_xGa_{1-x}As_ySb_{1-y}$ layers ($x = 0.2$–0.5, $y = 0.02$–0.03) grown by liquid-phase epitaxy (LPE). This technique has been commonly used for GaSb-compounds epitaxy. In particular, we investigate temperature changes of the energy and intensity of the layer emission in a wide temperature range (14–295 K).

LPE growth was performed in horizontal graphite reactor in hydrogen atmosphere with purity better than 0.5 ppm H_2O. Cooling rate was maintained on the level of $v = 1$ deg/cm. Layers of $Al_xGa_{1-x}As_ySb_{1-y}$ were grown on (100) oriented n-GaSb substrates ($n = 5\times10^{17}$ cm^{-3}). Growth temperature was applied in the range of $T = 530$–600°C. The lattice mismatch $\Delta a/a$ of the layers, determined by X-ray diffraction, was between 10^{-4}–10^{-3}. Thicknesses of $Al_xGa_{1-x}As_ySb_{1-y}$ layers were in the range of $d = 0.7$–2 μm. The photoluminescence (PL) experiments were performed using a Digichrom 240 monochromator and a liquid-nitrogen-cooled Ge detector. The investigated layers were mounted in a Leybold closed-cycle cryostat and illuminated by 488 nm line of Ar^+ laser.

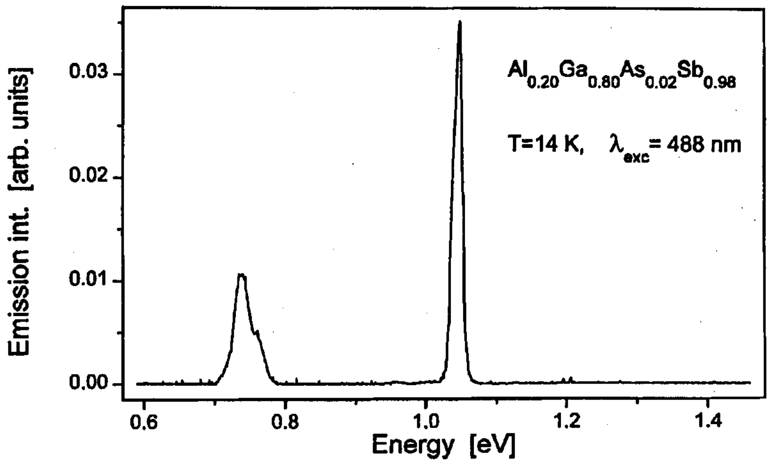

Fig. 1. Photoluminescence spectrum of $Al_{0.20}Ga_{0.80}As_{0.02}Sb_{0.98}$/GaSb structure measured at 14 K.

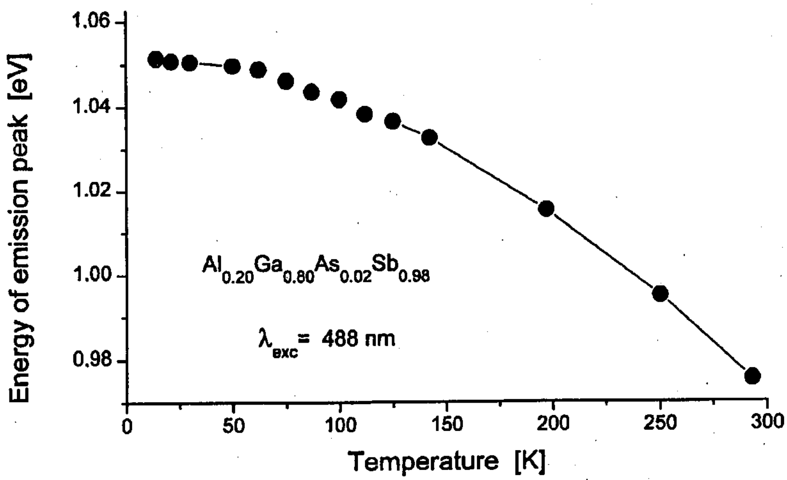

Fig. 2. Temperature changes of energy of the $Al_{0.20}Ga_{0.80}As_{0.02}Sb_{0.98}$ layer emission.

In Fig. 1 the PL spectrum of $Al_{0.20}Ga_{0.80}As_{0.02}Sb_{0.98}$/GaSb structure, measured at 14 K, is shown as an example. The thickness of the investigated layer is 2 μm. The spectrum is composed of two main peaks. Emission in the energy range 0.7–0.8 eV is related to recombination via band–acceptor or donor–acceptor pair transitions in GaSb substrate. Emission at $\approx$ 1.05 eV arises from band-to-band transition in the $Al_{0.20}Ga_{0.80}As_{0.02}Sb_{0.98}$ epilayer. Full width at half maximum (FWHM) of this PL peak at 14 K is 16.8 meV, indicating quite high purity of the material. Temperature evolution of energy and integrated intensity of the $Al_{0.20}Ga_{0.80}As_{0.02}Sb_{0.98}$ layer emission is shown in Figs. 2 and 3, respectively.

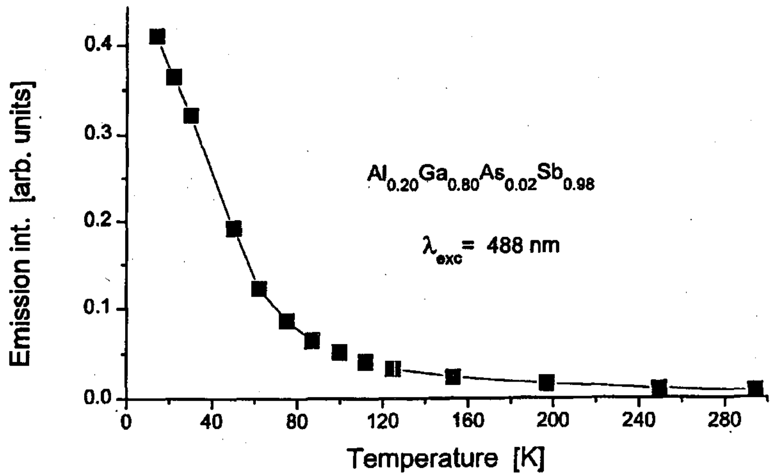

Fig. 3. Temperature changes of integrated intensity of the $Al_{0.20}Ga_{0.80}As_{0.02}Sb_{0.98}$ layer emission.

Calculating numerically first derivative of the dependence presented in Fig. 2, we can estimate a rate of temperature changes of band-to-band transition energy to be −0.3 meV/K and −0.45 meV/K at 150 K and 295 K, respectively. Low-temperature part (from 14 K to 30 K) of the emission intensity changes shown in Fig. 3 may be characterized by deactivation energy of $\Delta E = 0.6$ meV which is close to the value of ionization energy of free excitons in this type of materials [4, 5]. A reason of the emission intensity changes in high-temperature part will be a subject of further studies.

Comparing the PL spectra obtained during studies of other $Al_xGa_{1-x}As_ySb_{1-y}$ layers with different x and y compositions (e.g., $x = 0.2$, $y = 0.018$, 0.020 or 0.021), we can see a shift of emission energy due to the change of the band gap of the investigated layers. In case of small composition changes (e.g. 0.2% change of y) we do not observe significant differences in the widths of measured PL peaks. However, greater increase in x composition, e.g., from 0.2 to 0.3, generates increase in FWHM of the $Al_xGa_{1-x}As_ySb_{1-y}$ emission peak measured at 14 K from 16.8 meV to 20.2 meV. This fact is mainly related to the increase in alloy disorder in the layer with higher Al composition.

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