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TEMPERATURE DEPENDENCE OF PHOTOLUMINESCENCE IN InGaAsP/InP STRAINED MQW HETEROSTRUCTURES

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Multiple quantum well (MQW) InGaAsP/InP heterostructure systems have been drawn considerable research interest in recent years due to its suitability for long wavelength opto-electronic devices[1]. The performance of such devices is strongly affected by peculiarities of recombination processes in the quantum wells[2] (QW).

The goal of this study was to investigate the effect of barrier width on the radiative recombination of carriers. In our study, the photoluminescence spectra from InGaAsP/InP MQW double heterostructures have been measured in the 77-290 K temperature range with different excitation intensities.

A set of samples with fixed well width and various barrier thickness were grown on n^+-type InP substrates in a low-pressure metalorganic chemical vapor deposition (MOCVD) reactor. The undoped active MQW region consisting of 9x70 A strained wells of InGaAsP (band gap value $\lambda \cong 1.35\ \mu$) and 8x80 A, 100 A and 150 A lattice-matched barriers of InGaAsP ($\lambda \cong 1.12\ \mu$) (samples #382, #380 and #381 correspondingly) was confined by 500 A undoped InGaAsP ($\lambda \cong 1.12\ \mu$) separate confinement layers and embedded between *n*- and *p*-cladding InP layers. A mode-locked Nd^{3+}:YAG laser with second harmonic generation system (1064 nm and 532 nm) was used as an excitation source in all our measurements and PL spectra were recorded on 0.25 m SPEX spectrometer using standard lock-in technique.

The photo-generated carriers in MQW region can effectively screen the built-in field and thus cause change in the measured spectra. To account for this effect, a series of PL spectra at different excitation intensities were measured. Within 2.5 decades of pump intensities we did not observe any significant line shape or peak position changes, indicating that excited carrier densities were relatively low.

PL spectra of the samples at 77 K are shown in Fig. 1 (λ_{exc} = 532 nm). The peaks at 1.23 μ are assigned to radiative recombination of carriers in the QW, while the 1.07 μ peaks are due to the emission from barrier layers and confined layers.

Fig. 2 shows the temperature dependence of the integrated peak intensities of the QW. We found that the decrease rate of the QW PL intensity varied with the sample structure, being the highest for the sample with 80 A barriers and the lowest for 150 A, which may be caused by some barrier-dependent non-radiative recombination mechanism. For comparison, we evaluated carrier tunneling and thermionic lifetimes for each sample, based on transfer matrix calculations and thermionic emission theory[3] (see Table 1, material parameters from Adachi[4]). The estimated average electric field was 35-45 kV/cm. These calculations predicted that 100 A barrier sample PL data should be placed closer to that of 80 A sample, rather than 150 A sample, which seemed not agree with our measured results. Therefore a model including non-radiative recombination processes and possible space charge effects is required to more adequately describe the experimental data.

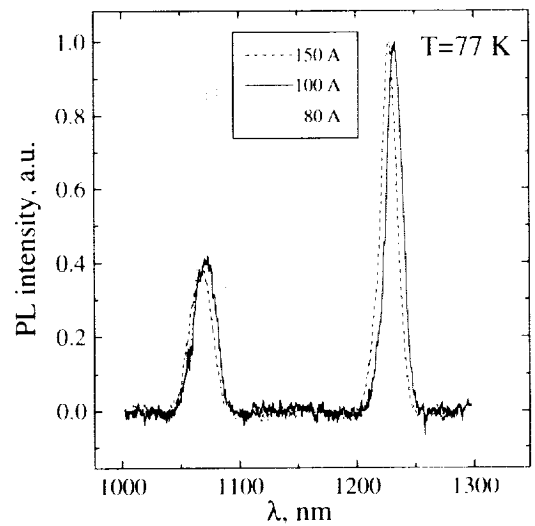

Figure 1. Normalized PL spectra of InGaAsP MQW *p-i-n* structures at 77 K: solid line - barrier width = 100 A, dotted line - 80 A, dashed line - 150 A. Excitation wavelength 532 nm, 30 W/cm^2.

Table 1. Calculated tunneling and thermionic escape times. Numbers in ( ) give the value at 77 K.

sample	barrier width , A	tunneling time			thermionic time, T=290 K(77 K)		
		electron	light hole	heavy hole	electron	light hole	heavy hole
#381	150	0.6 ps	17 ps	6.6 sec	0.2 ps (8 ps)	0.78 ps (820 ps)	8 ps (0.4 μs)
#380	100	0.12 ps	2 ps	0.2 msec	0.17 ps (6 ps)	0.6 ps (560 ps)	7 ps (0.2 μs)
#382	80	0.06 ps	1 ps	4 μs	0.16 ps (5 ps)	0.6 ps (480 ps)	6.7 ps (9 μs)

We found that the PL intensity is proportional to excitation intensity for 0.3 - 45 W/cm^2 range, without evidence of saturation. It may indicate the fast escape of the carriers from the wells.

We compared our PL spectra with absorption measurements and found that the QW PL peak positions of all samples were shifted by 8-10 meV up on energy scale in respect to the corresponding excitonic absorption peaks. This suggests band-to-band transitions as a dominant radiative recombination process. In addition, we found that QW PL peak position shows essentially the same temperature dependence as that of band gap of bulk InGaAsP alloy. This is similar to the results reported[5] for InGaAs/InP MQW structures.

In conclusion, the temperature and intensity dependencies of PL were investigated in InGaAsP/InP MQW double heterostructures with different barrier thickness. The radiative efficiency at 293 K was found to be smaller than that at 77K by a factor of 60-95 %, depending on the barrier width. The decrease rate of the QW PL intensity for 80 A barrier sample was observed to be higher than that for 100 A and 150 A ones.

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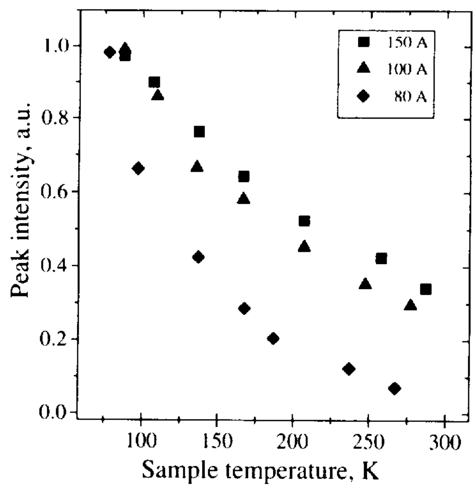

Figure 2. - integrated QW PL peak intensities as a function of the sample temperature. Squares - barrier width = 150 A, triangles - 100 A, diamonds - 80 A.

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