Influence of nitrogen on the optical transitions in $In_xGa_{1-x}As_{1-y}N_y/GaAs$ single quantum well structures for $y \leq 0.05$

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The novel material – $In_xGa_{1-x}As_{1-y}N_y$, has recently attracted considerable attention for possible optoelectronic applications for long-wavelength optoelectronic devices e.g. optical fibre communication. To investigate the optical properties of $In_xGa_{1-x}As_{1-y}N_y/GaAs$ single quantum well (SQW) structures the photoreflectance (PR) and the photoluminescence (PL) measurements were performed.

We have investigated a number of $In_xGa_{1-x}As_{1-y}N_y/GaAs$ SQW structures grown by solid source MBE with nitrogen concentrations up to $y = 0.05$ and high indium concentrations $x = 0.28 \div 0.40$. The width of quantum well ranges from 6.5 to 9.0 nm.

Photoreflectance data were taken at room temperature. For all structures besides of high-energy transition originating from GaAs, the 11H optical transition originating from SQW was observed. For some structures higher energy QW optical transitions are visible at the spectra, too. Besides of 11L and 22H transitions, which are allowed we observed the forbidden QW transitions e.g. 13H and 23H. Observation of forbidden transition is possible due to the presence in the structures weak electric field what is confirmed by the presence of short period Franz-Keldysh oscillations above the GaAs resonance. The identification of optical transitions was possible due to the theoretical calculations based on the envelope function model applied to structures being under study. With increasing nitrogen content, we observed the relatively high red shift of the optical transition energies. When fitting the 11H transition energy dependence on nitrogen we found that it decreases of 48 meV for every percent of nitrogen for structures with SQW width of 8 nm, In content of 40% and N content $y = 0 \div 0.05$ and 166 meV for structures with SQW width of 9 nm, In content of 28% and N content $y = 0 \div 0.005$.

PL measurements were performed to study the temperature dependence of 11H transition energy. Experimental data were fitted using the empirical Varshni model. The values of Varshni parameters are in good agreement with published data. We found that for structures with higher N content the temperature dependence of 11H transition energy is weaker in comparison to the structures with lower N content. Fitting with Varshni model to PL data showed that carriers are almost fully delocalised. Only at low temperatures a localisation of the carriers is present. For example, for structures with x = 0.4 the localisation energy changes from 1 to 8 meV, depending on N content. For the structures with low nitrogen content the experimental data coincide with the fit except very low temperatures but localisation energies are low. That demonstrates that N has no particular impact on carrier localisation. That is not true for structures with rather high N content. At low temperatures we can observe S-shaped energy peak behaviour for structures with high nitrogen content.