TITLE: Photoluminescence Study of InP Nanoscale Islands Grown by MOVPE in InGaAs/GaAs Matrix

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Photoluminescence study of InP nanoscale islands grown by MOVPE in InGaAs/GaAs matrix

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Abstract. Photoluminescence study (PL) of the self-assembling Stranski–Krastanov growth of InP nanoscale islands embedded in $In_{0.49}Ga_{0.51}P$ matrix by low pressure metal organic vapor phase epitaxy are presented. The temperature and the excitation level dependencies of the external quantum efficiency of these structures were investigated. InP nanoislands demonstrate a high quantum efficiency at 77 K and high PL wavelength temperature stability.

Introduction

The self-assembling homogeneous and coherent nanoscale islands (NSIs) formation in strongly strained semiconductors have been a subject of intensive investigation due to the 3D confinement of carriers in island's volume. Recently the quantum dot lasers with low threshold current and high characteristic temperature have been presented for In(Ga)As/GaAs growth system [1]. But the most short-wavelength laser structures with InP NSI active region embedded in $In_{0.49}Ga_{0.51}P$ matrix matching to GaAs (100) substrate grown by MBE have exhibited the pulse generation only at 90 K [2]. For increasing of working temperature of such structures it is necessary to study the temperature and power dependencies of external quantum efficiency.

1 Experimental

In this paper we present external quantum efficiency as a function of the temperature and the excitation level in heterostructures with InP NSI grown by low pressure MOVPE [3]. Structures with InP NSI grown by MOVPE [3–5] demonstrated that: (i) the energy peak is not shifted with the increase of amount of deposited island material, (ii) the quantum efficiency at 77 K is very high. Fig. 1 demonstrates the temperature dependence of photoluminescence (PL) peak for InP NSI with nominal deposition thickness of 5MLs at excitation level 50 W/cm^2. This structure revealed 30% of the external quantum efficiency at 77 K. The temperature dependence of InP NSI peak is more smooth than that of InGaP matrix and compressive strained quantum well with 6 MLs thickness (calculated) (Fig. 1).

Fig. 2 shows the temperature dependence of external quantum efficiency (η) for the structure of 5 MLs InP nominally. PL efficiency falls drastically with measuring temperature increase. The characterization temperature T_0 for this structure [$\eta = \eta_0 \exp(-T/T_0)$] decreases from 61 K to 13 K that may be connected with the increase of the electron leakage from NSI into the InGaAs matrix [6]. Low temperature (77 K) PL spectra of InP NSIs with deposition thickness of 3 ML (solid lines) and 5 ML (dash lines) at various excitation levels are shown in Fig. 3. These spectra are the superposition of two PL peaks: NSI and wetting layer. At low excitation level ($P = 10{-}30\,\mathrm{W/cm^2}$) only NSI peak is observed and therefore the position of PL peaks of these two structures is the same. The increase of excitation level results in the appearance and enhancement of the short-wavelength peak

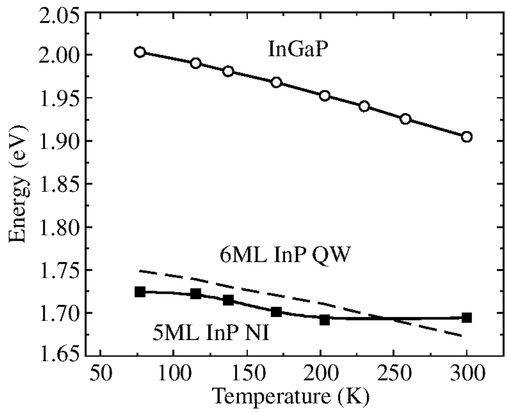

Fig. 1. PL temperature dependence for 5 ML InP NSI (solid square), InGaP matrix (open circle) and 6 ML Quantum Well (dash line), $P = 50\,\mathrm{W/cm^2}$.

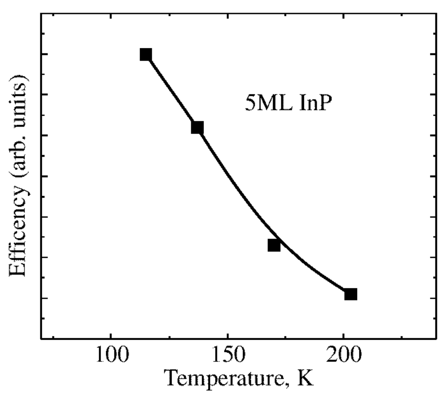

Fig. 2. Temperature dependence of quantum efficiency of 5 ML InP NSI, $P = 50\,\mathrm{W/cm^2}$.

corresponding to the wetting layer radiation and further to the saturation of radiative NSI transitions. More strong spectral shifts for the structure with 3 ML deposition thickness compared with 5 ML ones can be explained by lower island density in 3 ML structure and therefore luminescence saturation of InP NSI occurs at lower excitation density.

In Fig. 4 the temperature dependencies of the PL spectra of the structures with 3 ML deposition thickness and 5 kW/cm^2 excitation level are displayed. As the temperature increases the wetting layer short-wavelength peak decreases; at $T > 230$ K only one peak connected with NSIs in PL spectrum is detected. In our opinion this phenomenon is related with the more intensive electron leakage from the wetting layer into the InGaP matrix in comparison with InP NSI at temperature increase.

2 Conclusions

The external quantum efficiency measurements as a function of the temperature and excitation level were performed. It was shown that InP NSIs grown by MOVPE method [4] were formed as coherent islands. The amount of deposited material influences only on the density of the NSIs but not on there size. Grown InP NSIs demonstrated high quantum efficiency at 77 K and high wavelength temperature stability at low excitation level. At

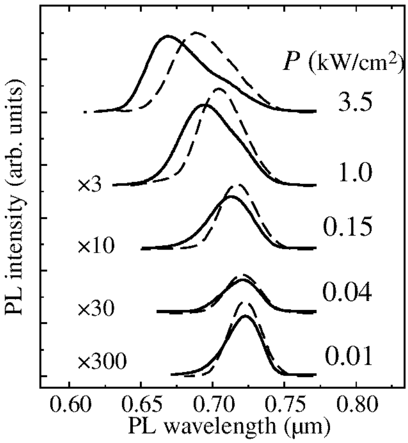

Fig. 3. 77 K PL spectra of 3 ML (solid line) and 5 ML (dash line) InP NSIs at different excitation level.

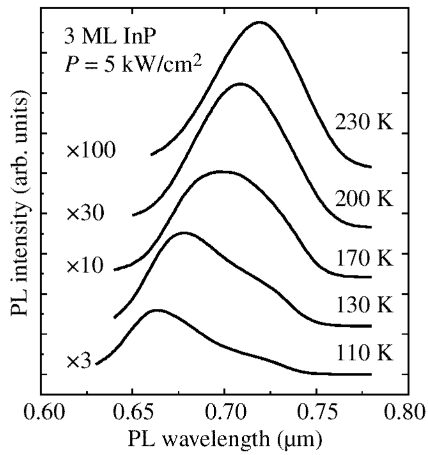

Fig. 4. PL spectra of 3 ML InP NSI s at high excitation level (5 kW/cm^2) for different measuring temperatures.

high excitation level the InP NSI luminescence was saturated and wetting layer radiation became dominant. The rise of the external quantum efficiency at 300 K and suppression of InP NSI emission saturation can be probably achieved by the increase of a number of separated InP layers or using more wide-gap materials for matrix, e.g. (AlGa)InP.

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