

## Time-resolved photoluminescence of InGaN/GaN MQW structures

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The structures containing InGaN/GaN quantum wells (QW) attract big attention because of their use in blue lasers and field effect transistors of new generation. Although optical properties of InGaN/GaN MQW, photoluminescence (PL) in particular, were examined in a number of papers, the nature of  $e$ - $h$  recombination is still hotly debated. Two models, the recombination model of excitons localized on alloy fluctuations [1] and recombination model of free carriers in QW with strong piezoelectric field induced by pseudomorphic strain [2], are widely used for interpretation PL data. However, some of experimental features observed earlier in PL spectra of InGaN/GaN MQW structures meet difficulties in understanding within the frameworks of both models.

In this paper we report on time-resolved PL of  $\text{In}_x\text{Ga}_{1-x}\text{N}/\text{GaN}$  MQW structures and suggest a modified model of donor-acceptor recombination in QW (DARQW) to explain the observed spectral kinetics. The structures were grown by low-pressure MOCVD technique on sapphire substrates and contained 12  $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$  layers of 60 Å width separated by 60 Å GaN barriers. In the experiment we have studied both undoped and doped with Si at a level of  $10^{18} \text{ cm}^{-3}$  InGaN/GaN MQW structures. Time-resolved PL measurements at temperatures 4.2 – 77K have been performed with nanosecond time resolution using a pulsing nitrogen laser ( $\lambda_{ex} = 337 \text{ nm}$ , 6 ns pulse width). Excitation density,  $I_{ex}$ , was varied within the interval  $0.6 - 10^4 \text{ W/cm}^2$ .

The examined MQW structures exhibit strong PL in the region of 2.6-3.0 eV. At low excitation densities and small delay times PL spectrum of Si-doped MQW structure consists of a single asymmetrical PL band with the peak energy at 2.781 eV and the FWHM of 83 meV (Fig. 1). The peak energy of the band is blue shifted with  $I_{ex}$ . The shift with  $I_{ex}$  is accompanied by an increase of the FWHM of the PL band. Time-resolved PL spectra show a red shift of the PL band peak energy with delay time. Crucial evidence giving a clue towards the model responsible for the observed behavior of PL comes from the time dependence of PL,  $I_{PL}(t)$ . Experimentally it follows a power law,  $I_{PL}(t) \propto t^{-g}$ , rather than monoexponential or multiexponential dependencies. This is observed over the whole PL band, though the power,  $g$ , depends on PL energy. Parameter  $g \approx 2$  at PL energies below 2.78 eV. Similar regularities of PL spectra we observed for both groups of samples, doped and undoped, studied in this paper. The sum of observed experimental evidences suggests the mechanism of PL in InGaN/GaN MQW similar to the recombination of donor-acceptor pairs (RDAP) [3]. However, unlike the bulk case the impurity centres participating in such recombination are localised in the QWs and therefore have a fixed minimal spatial separation in the direction perpendicular to growth axis, whereas in-plane of the QW there are generally no restriction on relative distribution of impurities. This modified model can be treated as the two-dimensional donor-acceptor recombination (2D-RDAP). In this report we discuss the models of  $e$ - $h$  recombination in alloy MQW used in [1,2] as well as the observed evidences that favour the model of 2D-RDAP recombination. This model satisfactorily describes the observed shapes of PL time dependencies, and PL spectra. It delivers the energy of participating in recombination process impurities. The details of a similar approach used for bulk GaN was recently published in [3].

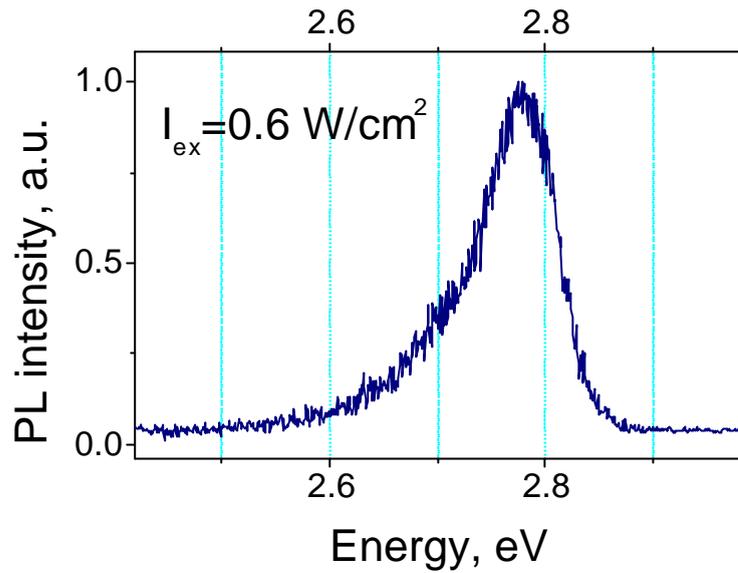


Fig.1. PL spectrum at zero delay time for Si doped MQW InGaN/GaN structure.  $T=4.2$  K.

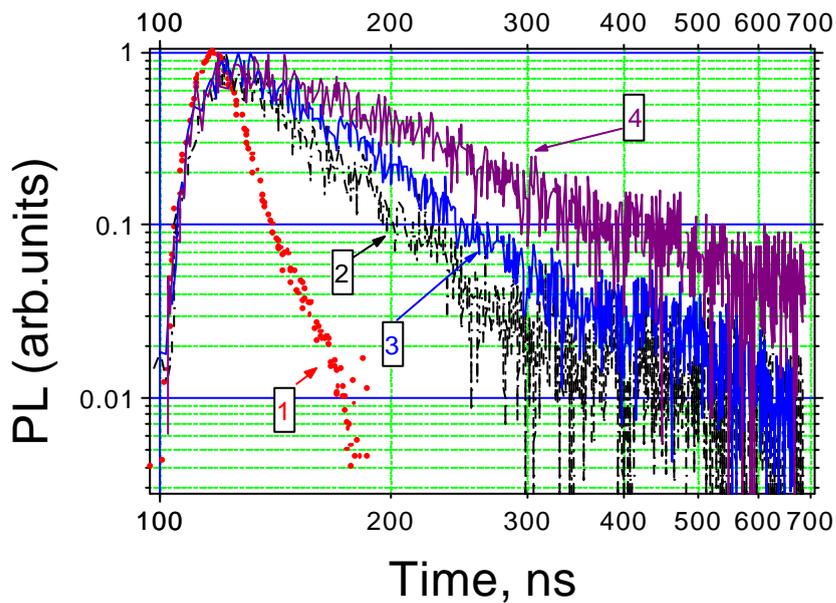


Fig. 2. PL decay kinetics for doped MQW structure.  $I_{ex}=0.6$  W/cm<sup>2</sup>,  $T=4.2$  K.

1 - Laser pulse; 2 - PL signal at 2.83 eV; 3 - PL signal at 2.80 eV; 4- PL signal at 2.70 eV.

**References:**

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