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Photo-induced transient spectroscopy and in-plane photovoltage in GaInNAs/GaAs quantum wells

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Abstract

We have studied the optical quality of sequentially grown undoped $Ga_{0.8}In_{0.2}As$ and $Ga_{0.8}In_{0.2}N_{0.015}As_{0.985}$ quantum wells (QWs). Spectral and time-resolved in-plane photovoltage (IPV) and photo-induced transient spectroscopy (PITS) techniques were used in this investigation. Two clear peaks have been observed and analysed in the PITS experiment. Spectral and transient IPV in the same samples has been investigated and a selective light was used as the excitation source to separate the GaInNAs IPV from the other layers. IPV can be explained in terms of random fluctuations of the Fermi level in undoped QWs. Spectral and time-resolved IPV measurements can therefore be used to obtain qualitative and quantitative information about interband transitions and trap activation energies.

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Keywords: GaInNAs; In-plane photovoltage; PITS; Fermi level fluctuation

1. Introduction

The quaternary alloy GaInNAs promises to be an ideal material system for many applications in opto-electronics. The difficulty of incorporating nitrogen in GaInAs has provoked much work to understand the factors affecting the optical quality, such as composition, growth and annealing conditions [1].

In this work, we used two different techniques to investigate the presence of defects and traps in nitrogen free and nitrogen containing quantum wells (QWs).

2. Results and discussion

The sample studied was grown using molecular beam epitaxy [2] and fabricated in form of single bar with a 1 mm^2 optical window where the exciting light was incident on. The structure contains two undoped 9 nm QWs, one $Ga_{0.8}In_{0.2}As$ and the other

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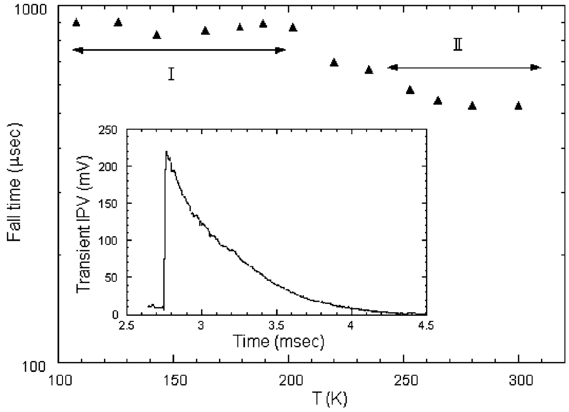

Fig. 1. Temperature dependence of fall time in transient IPV. The inset shows a typical exponential decay of IPV recorded $T = 108$ K.

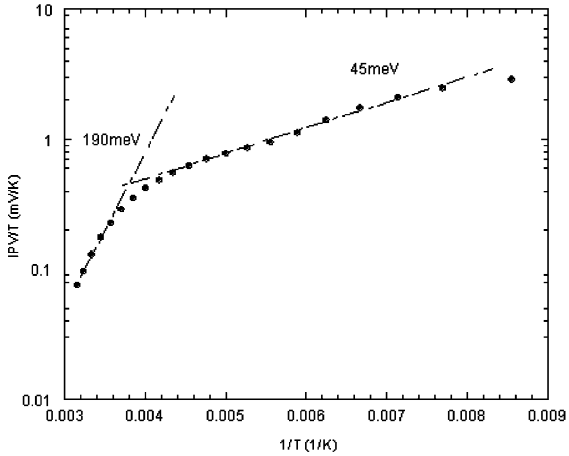

Fig. 2. Temperature dependence of the IPV signal in CW mode.

$Ga_{0.8}In_{0.2}N_{0.0135}As_{0.985}$, separated by a 50 nm GaAs spacer.

Previous room temperature (RT) PL studies [2] showed that the spectrum of the sample consists on a GaInAs-associated peak and a GaInNAs one at 985 and 1235 nm, respectively.

Standard PITS experiments were carried out to detect and characterise deep traps in the temperature range of 77–350 K. A long pass filter with the white light source was used for excitation of GaInNAs layer only. Two clear peaks have been found, corresponding to two different trap levels with activation energies of 150 and 300 meV. These compare quite well with other research groups [3,4].

Two different trap levels have been found using an alternative technique, the IPV, which arises from Fermi level fluctuations along the QW layers of the structure [5]. Temperature, excitation intensity, spectral and time-dependent study of the open circuit IPV gives information about the non-radiative centres and hence about the optical quality of the material. It also provides information about the radiative transition energies in all the layers, as it carries the same spectral information as the absorption coefficient. The results can be explained in terms of effective p–i and n–i junctions randomly distributed along the nominally undoped layers [5,6]. Figs. 1 and 2 show the temperature dependence of the IPV signal in the transient and CW, using the 1.064 μm emission of an Nd:YAG laser as excitation source.

Two regions can be distinguished in both figures, corresponding to two non-radiative centres, as indicated I and II in Fig. 1. The activation energies can be found from Fig. 2 as 190 and 45 meV.

We have developed [7] a model to explain the role of traps in the IPV dynamics, where the expressions have been derived for trap emission energies and de-trapping rates of photogenerated carriers as well as the spectral and excitation intensity dependence of the IPV.

3. Conclusions

The optical quality of sequentially undoped grown GaInAs and GaInNAs QW has been studied using the in-plane photovoltage (IPV) and photo-induced transient spectroscopy (PITS) techniques. These techniques allow the identification of traps and defect levels in the structure.

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