DEEP LEVEL INVESTIGATION ON GaAsN STRUCTURES BY DLTS METHOD

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1. Introduction

Relatively new materials of nitride compounds A_{III}-B_V-N which attract attention with their famous properties: temperature independent band gap uses for solar cells, lasers with long wave length, optical amplifiers. Decreasing of band gap width causing a presence of nitrogen in this compounds about 100 meV per 1% of nitrogen allows settings emission length near infrared spectra. On the other hand presence of nitrogen indicates creation of the deep energy levels in the band gap region [1].

The aim of this work is to identify parameters of electrically active defects in $GaAs_{1-x}N_x$ structures with different concentration of nitrogen by DLTS method.

2. Experiment

Four $GaAs_{1-x}N_x$ compounds with Schottky barriers were made by Wrocław University of Technology using AP-MOVPE method [2]. Schottky contact was evaporated with gold on UD $GaAs_{1-x}N_x$ and an ohmic contact with silver paste coated on substrate on IEF STU in Bratislava.

Tab. 1. *Composition of investigated structures* [3]

structure	substrate	UD GaAs buffer	$GaAs_{1-x}N_x$	
N50n	n-GaAs:Si (100)	0.45 μm	180 nm	x = 1.10 %
N42n	n-GaAs:Si (100)	0.45 μm	180 nm	x = 1.41 %
N54n	n-GaAs:Si (100)	0.45 μm	180 nm	x = 2.48 %
N44n	n-GaAs:Si (100)	0.45 μm	180 nm	x = 2.65 %

IV characteristics were obtained by Agilent 4155 (Semiconductor parameter analyser).

The CV and DLTS measurements were made utilizing measuring workplace BIORAD DL8000 DLTFS in the experimental laboratory of the Institute of Electronics and Photonics FEI STU in Bratislava.

Digital DLTS - DLTFS (Deep Level Transient Fourier Spectroscopy) method measures the complete capacitance transient as a C(t) array and transfers the data into a computer system. Using a Fourier transformation and the direct evaluation the time constant and the transient amplitude can be evaluated for every transient measured at any temperature.

DLTS spectra were carried out by software Dlts 2.6 – “Direct auto Arrhenius Single level” and “Direct auto Arrhenius Multi level”. “Direct auto Arrhenius” uses direct capacitance transient measurements measured during temperature scan. Every capacitance transient is characterized with number (Exponential class) that indicates the quality of each transient. Exponential class shows possibility of occur deep energy level. Transients measured during temperature scan multiplied with 22 different functions gives 22 different types of DLTS signal uses in manual evaluation. Therefore, only one temperature cycle is necessary for measuring the activation energy of a deep energy level. The direct evaluation works perfect on single exponential transients caused by one isolated trap level [4]. Complicated measured signals can be evaluated in a better way, which in our measurement system is called “Direct auto Arrhenius Multi level evaluation”, which using mathematical deconvolution. Arrhenius plot is getting from these two evaluations methods.

3. Results and discussion

The asymmetric shape of measured IV characteristic indicates Schottky structure properties of our compounds. Measured CV characteristics had expected shape typical for Schottky diode (Fig. 1). CV characteristic measured on structure N50n with the lowest concentration of nitrogen is shifted to lower values of capacitance than structures N42n, N44n and N54n. Shapes of CV characteristics of N42n, N44n and N54n are very similar in high temperatures (e.g. 450 K Fig. 1 b). Further investigations are needed.

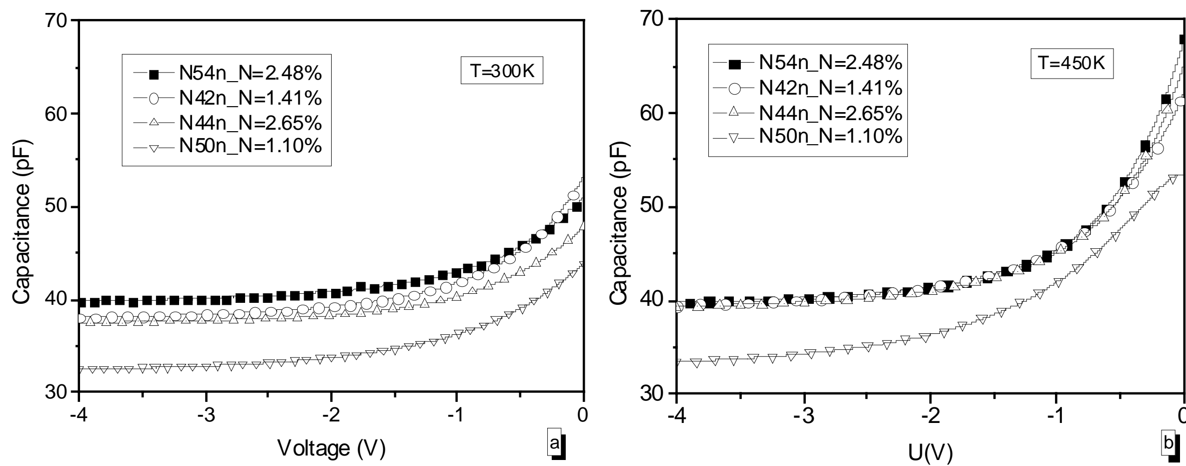

Fig. 1: *CV curves measured in a) 300K temperature and b) 450 K.*

Fig. 2 shows standard DLTS signal of four investigated structures with different concentrations of nitrogen measured with these input parameters $T_w = 2$ s, $t_p = 100$ ms, $U_R = -1.5$ V, $U_P = -0.01$ V. Extermination of DLTFS spectra is a result of increasing concentration of nitrogen. Significant peak in temperature T = 350 K indicates that the same defect is present in all measured structures. Concentration near 3% of nitrogen is responsible for creation of most traps and point defects [4]. The presence of more than one defect in the structure of the sample N44n (nitrogen concentration about 2.68 %) indicates approaching to the critical concentration.

Fig. 3 shows comparison of Arrhenius plots of ET1, ET2, ET3, ET4, ET5 electron-like deep energy levels and HT1 hole-like deep level obtained from “Direct auto Arrhenius Single level” and “Direct auto Arrhenius Multi level”.

Tab. 2. shows parameters of each deep energy trap identified by single level “Direct auto Arrhenius Single level” and “Direct auto Arrhenius Multi level”.

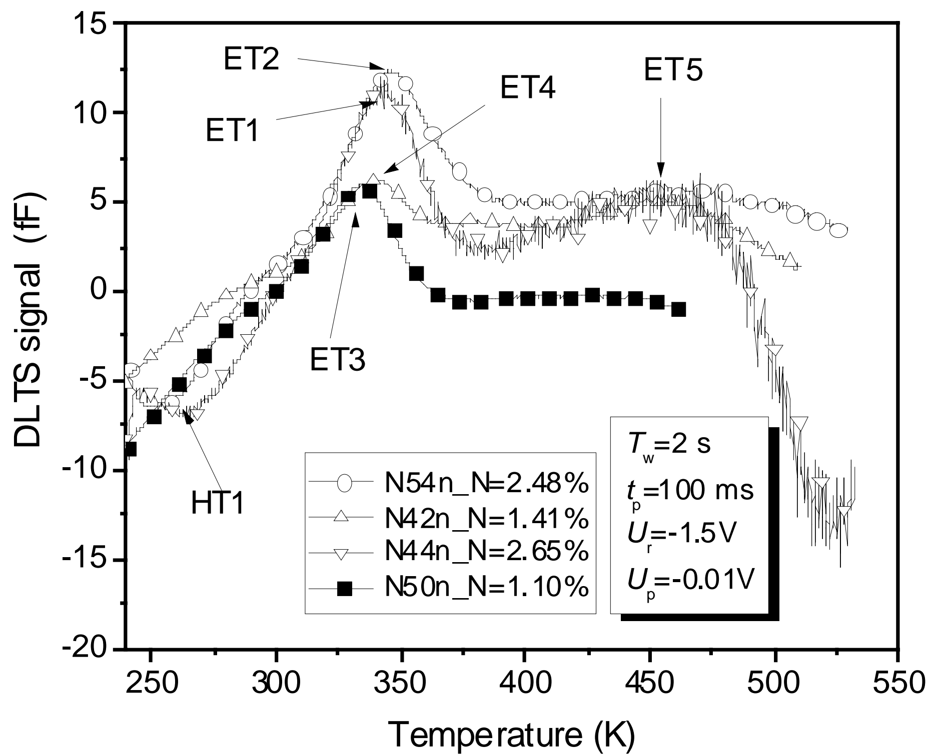

Fig. 2: *DLTS spectra of $GaAs_{1-x}N_x$ structures with different concentrations of nitrogen.*

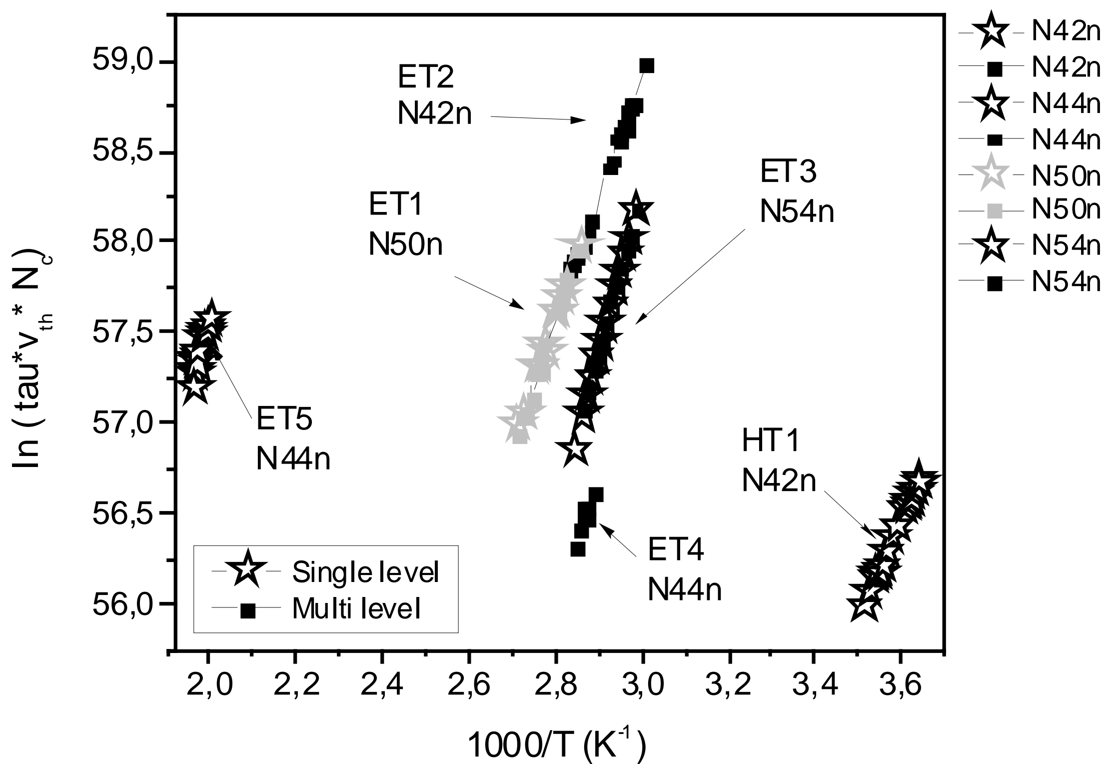

Fig. 3: *Comparison of Arrhenius plots obtained from obtained from "Direct auto Arrhenius Single level" and "Direct auto Arrhenius Multi level".*

Tab.2. *The parameters of deep energy levels evaluated from Arrhenius plots*

Structure	Method	Trap	E_T (eV)	σ_T (cm^{-2})	N_T (cm^{-3})	Temperature (K)
N50n	Single level	ET1	0.605	3.36E-17	6.38E+13	360
	Multi level	ET1	0.563	8.68E-16	6.49E+13	350
N42n	Single level	HT1	0.463	7.28E-17	3.36E+13	280
	Multi level	ET2	0.571	1.11E-17	5.83E+13	350
N54n	Single level	ET3	0.785	3.51E-14	3.36E+14	340
	Multi level	ET3	0.776	2.60E-14	3.36E+14	340
N44n	Single level	ET5	0.736	2.51E-18	2.9E+14	504
	Multi level	ET4	0.566	4.43E-17	1.44E+14	350

4. Summary

Deep levels in $GaAs_{1-x}N_x$ compounds have been studied by employing deep level transient spectroscopy (DLTS) method. Two different types of evaluation methods identified six deep energy levels: HT1 (E_C - 0.463 eV), ET1 = ET2 (E_C - 0.571 eV), ET3 (E_C - 0.776 eV), ET4 (E_C - 0.566 eV) and ET5 (E_C - 0.736 eV).

Traps ET1 and ET2 indicates the same deep energy level. Electron traps ET1 and ET2 have activation energy in range of 0.56 to 0.57 eV. The growth was presumably Ga- rich and therefore favouring incorporation of oxygen in As sites near the interface [5]. ET1 and ET2 probably corresponds to EL3 centres presented in [5].

The exact origin of other deep levels remains an open question and will be subjected for further investigations with complementary electrical and structural methods.

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