STUDY OF ELECTRICAL PROPERTIES OF AlGaN/GaN STRUCTURES BY DLTS METHOD

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1. Introduction

The AlGaN/GaN heterostructures for HEMTs are being under intensive investigation because of their unique electrical properties that are strongly affected by trapping effects due to deep traps in the structure [1, 2, 3].

This work deals with the identification of defects in AlGaN/GaN Schottky structures by DLTS method [4] before and after irradiation by high-energy electrons. After original DLTS measurements the set of samples were exposed with energy 5 MeV/750 W by linear electron accelerator. After irradiation the samples were measured under the same measurement conditions. The influence of irradiation on deep energy levels and their parameters before and after irradiation were investigated. The expressive changes in deep traps distribution were revealed from DLTS spectra and strong influence of irradiation on electrical properties was demonstrated. Experiments were carried out on measuring workplace DL8000 in the experimental laboratory of the Institute of Electronics and Photonics FEI STU in Bratislava.

2. Experiment

Test AlGaN/GaN structures were grown by low-pressure metal-organic vapour phase epitaxy (LP-MOVPE) on a sapphire substrate. The structure consists of 22 nm thick undoped $Al_{0.3}Ga_{0.7}N$ layer grown to 3 μm GaN buffer layer. Electron beam evaporation (EBE) was used for the deposition of Nb, Ti, Al, Ni metal contacts, while Au was deposited by the conventional resistance evaporation. The Schottky diode ohmic contacs consist of Nb (20 nm) / Ti (20 nm) / Al (100 nm) / Ni (40 nm) / Au (50 nm) layers. After rapid thermal

annealing at 850°C for 35 seconds in a nitrogen atmosphere, the contact resistance decreased to less than 3×10^{-6} Ω cm^{-2} forming alloyed ohmic contact. As the next step the mesa isolation (~100 nm) was formed by reactive ion etching AlGaN / GaN in CCl_4 gas plasma. EBE Ni (40 nm) / Au (130 nm) metal system in combination with the "lift off" technology was used to create a Schottky contact area of 4×10^{-4} cm^2.

For irradiation of samples a linear electron accelerator with electron beam energy of 5 MeV power 750W and radiation influence 3.3 μs with frequency of 150 Hz has been used.

The measurements were made utilizing measuring workplace BIORAD DL8000 DLTFS from ACCENT. Evaluation of the measured DLTS spectra was carried out by software Dlts 2.6. The obtained DLTS spectra were evaluated by Direct analysis DLTFS (Deep Level Transient Fourier Spectroscopy) and Tempscan maximum analysis.

3. Results and discussion

The set of DLTS spectra have been measured in wide range of parameters. Fig. 1 shows typical DLTFS spectra of Schottky diodes measured before irradiation. The sample in Fig 1, a was measured by following parameters: reverse bias V_R = -2.5 V, pulse bias V_P = -0.1 V, filling pulse width t_P = 0.8 s, T_W = 80 ms in temperature range 300K-550K. From the selected DLTFS spectra (Fig. 3, a) four deep energy levels (DL1 - DL4) have been revealed. The same sample measured by changed parameters as: reverse bias V_R = -3.2 V, pulse bias V_P = -0.2 V, filling pulse width t_P = 2 s, T_W = 2.5 s, in temperature range 100 K – 480 K is depicted on Fig 1, b. Similarly four deep energy levels (DL2, DL4, DL5, DL6) have been identified from the selected DLTFS spectra, while two of them (DL2, DL4) correspond with deep energy levels in Fig 1 a.

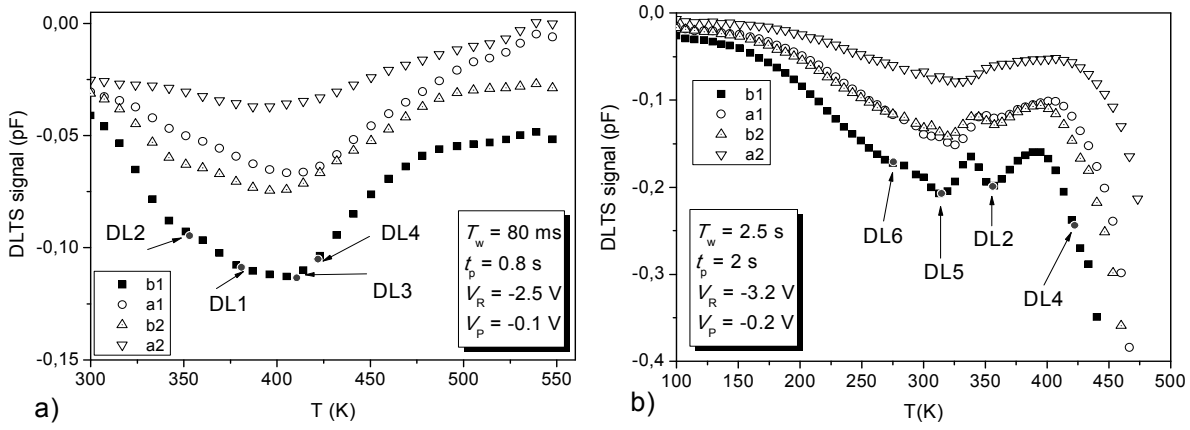

Fig.1: *Typical DLTS spectra measured before irradiation at different parameters*

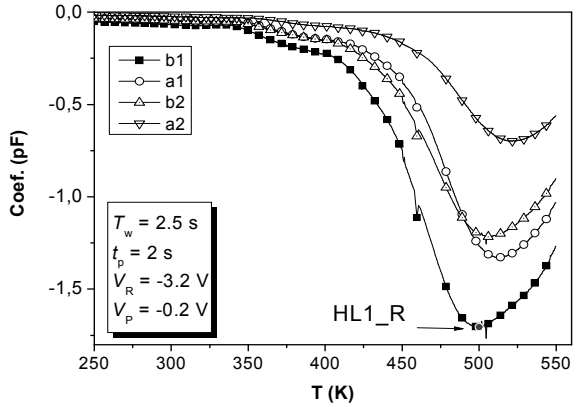

Fig. 2: *DLTS spectra measured on sample after electron irradiation*

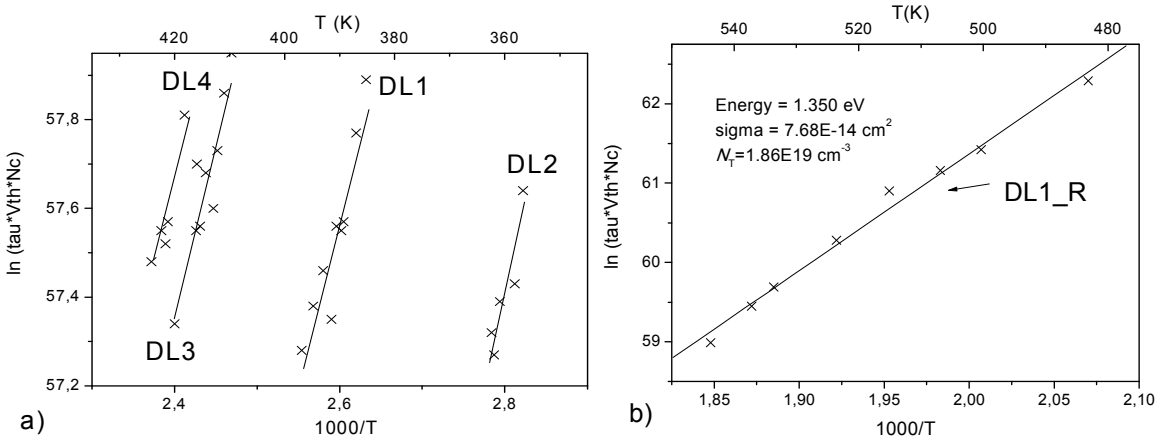

Fig. 3: *Arrhenius plot for sample before a) and after b) irradiation.*

Tab. 1. *The parameters of deep energy levels evaluated from Arrhenius plots.*

Deep energy level	*E_T (eV)*	*σ_T (cm^2)*	*N_T (cm^{-3})*	*Temperature (K)*
DL1	*0.65*	*3.04E-17*	*2.61E+18*	*380-395*
DL2	*0.76*	*5.85E-15*	*2.78E+18*	*350-365*
DL3	*0.69*	*2.61E-17*	*2.28E+18*	*405-420*
DL4	*0.92*	*1.21E-14*	*2.22E+18*	*415-425*
DL1_R	*1.35*	*7.68E-14*	*1.86E+19*	*480-550*

DLTFS spectra measured on sample after irradiation are displayed on (Fig 2). The initial measuring parameters were set as in measurements before irradiation while only one deep energy level (DL1_R) has been identified (Fig. 3, b).

4. Summary

DLTS spectra measured on the AlGaN/GaN Schottky structures before and after irradiation exhibit a strong deviation from an exponential dependence. Four deep energy levels have been identified in AlGaN/GaN Schottky structures before irradiation whereas the distribution of deep traps has changed after irradiation to one energy level (Tab. 1).

Deep energy levels DL1 – DL4 with activation energies obtained for the positive peaks, are thought to be related with the surface states localization [5-7]. Further studies of these hole-like traps caused by surface states in AlGaN/GaN heterostructures are needed.

The origin of deep energy level DL1_R (ΔET = 1.350 eV) obtained after irradiation of our sample was not identified yet and will be the subject for investigations also with other available methods.

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