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

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1. Introduction

Due to high demands for high power devices, the research has been focused on wide band gap semiconductors according to their favorable electronic properties. GaN is classified among attractive materials for high power switching devices and microwave amplifiers due to its high breakdown field and high sheet carrier density [1]. However, the major drawback to GaN-based electronic has been presence of large involuntary donor concentrations and the problems in controlling electronic properties [2]. This work deals with study of electrical properties of AlGaN/GaN Schottky structures by capacitance method (CV, Ct and DLTS).

2. Experiment

Test Schottky AlGaN/GaN structures (for HEMTs) were grown by low-pressure metal-organic vapor phase epitaxy (LP-MOVPE) on a sapphire substrate. The structures consist of two 8 nm thick undoped $Al_{0.3}Ga_{0.7}N$ sublayers and 6 nm thick Si-doped $Al_{0.3}Ga_{0.7}N$ layer in the middle. 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.

The CV, Ct 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. Capacitance-voltage (C-V) characteristics were evaluated by software Hermes, DLTS spectra were carried out by software Dlts 2.6.

3. Results and discussion

Fig. 1 a shows typical C-V curves measured on the sample with variable temperature conditions in the range 82 K – 500 K. As shown on picture after applying reverse bias voltage, the capacitance is slightly decreasing with increasing reverse voltage from 0 V. This effect is related to the shift of wave function of electrons located in QW on heterostructure's interface and also depends on Schottky contact interface [3]. The sudden fall of capacitance in the range of reverse voltage from -2 V to -3.5 V is caused by QW depletion. The exact location of heterostructure's interface below the surface (23 nm) was determined from the concentration profile to depletion region width dependence [4] (Fig. 1 b). The area around the voltage equal to -1.2 V (cross point Fig. 1 a) is essentially independent of temperature depth investigation.

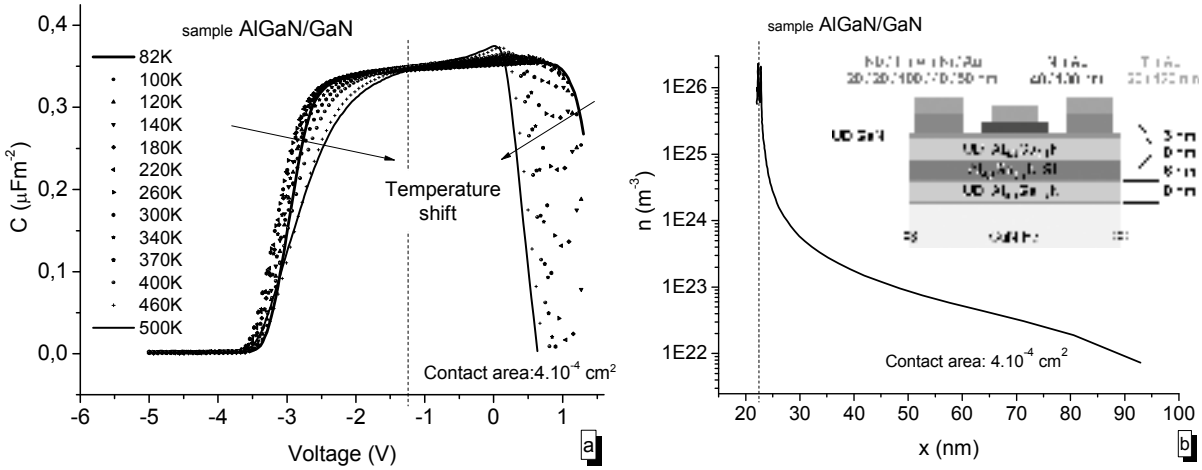

Fig.1: *a) CV curves measured in temperature range 82 K – 500 K, b) Calculated concentration profile of free charge region and technologic description of structure*

The free charge carrier density ($n_{2D} = 1.7\times10^{17}$ m^{-2}) was calculated as an integral of

concentration profile. To correctly evaluate the measured C-V curves, we have used following parameters of GaN semiconductor: the relative permittivity ε ~ 8.9, the band gap width $E_g(0)$ = 3.47 eV (300 K), and the intrinsic concentration $n_i = 3.22\times10^{-4}$ m^{-3} (300 K) [5].

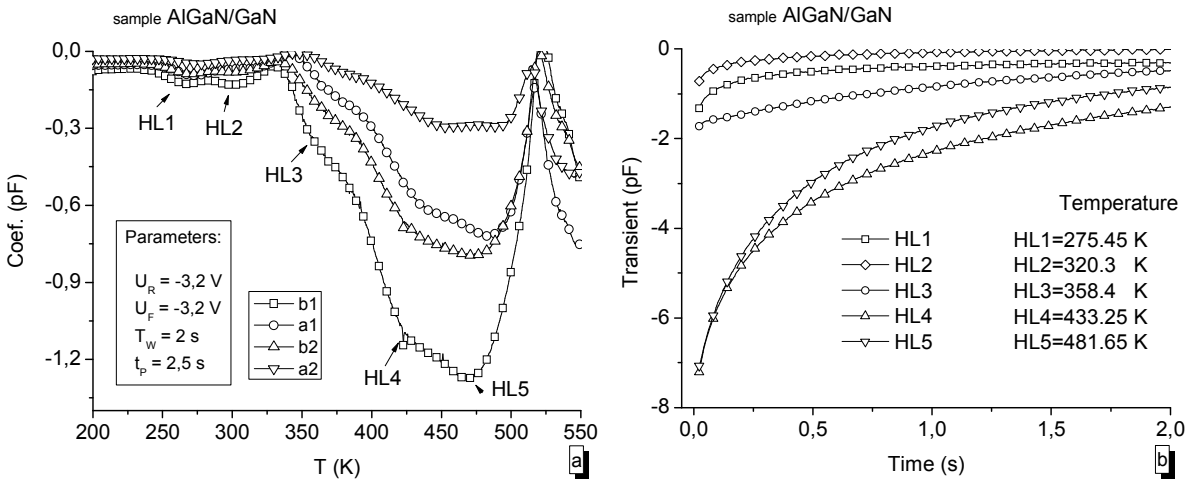

Fig. 3: *DLTS signal calculated with correlation function a,b a), capacitance transient b).*

Tab. 1. *The parameters of deep energy levels (HL1 - HL5) evaluated from Arrhenius plots.*

Deep energy level	E_T (eV)	σ_T (cm^2)	N_T (cm^{-3})	Temperature (K)	*Comparison with the parameters set out in publications*
HL1	0.58	3.65E-17	3.8E+17	263-280	consistent with surface localization 0,5eV [6]
HL2	0.77	3. 42E-23	3.2E+17	280-320	donor–acceptor pair and yellow luminescence band in GaN [7].
HL3	0.82	6.48E-17	1.3E+18	346-358	consistent with surface localization 0,76eV [6]
HL4	1.06	5.04E-14	6.4E+18	425-450	origin unknown
HL5	1.25	3.97E-14	6.1E+18	460-480	origin unknown

Fig. 2, a) shows selected DLTFS spectra measured on investigated sample (measuring conditions are mentioned in the chart). Transient characteristics measured on the same sample (Fig. 2, b)) exhibit a well exponential dependence.

We have used automatic evaluation methods to obtain deep energy levels (HL1 - HL5) from both DLTFS and capacitance transient characteristics and approved, that the

results for these energy levels are similar as by DLTFS spectra analysis. Basic parameters of these deep energy levels are described in the summary table (Tab. 1) along with origin of these defects and their references.

4. Summary

Cross point (independent on temperature depth) around -1.2 V range was observed. The position of heterostructure's interface set by the maximum of concentration profile was determined to 23 nm below the surface. Five hole-like deep energy levels (HL1 - HL5) have been identified from measured DLTFS spectra and capacitance transient. Basic parameters of these defects and comparison with the parameters set out in publications are described in the summary table (Tab. 1). The exact origin of this deep level remains an open question similarly as published in [7 – 10] and will be subjected for further investigations with complementary electrical and structural methods.

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