STUDY OF EMISSION AND CAPTURE PROCESSES IN ALGAN/GAN HEMTS FOR 5G

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Abstract *Deep Level Transient Fourier Spectroscopy experiments were realized to study emission and capture processes in AlGaN/GaN HEMT heterostructure with gold source-connected field-plate prepared by the MOCVD process on SiC substrates. The structures exhibited a variety of deep energy levels with low concentrations. Parameters of 11 defect states (8 electron-like states and three hole-like states) were identified. Calculated energies and possible origins of these results were confirmed by Arrhenius curve comparison. The presence of* N_{Ga}*-related defect, screw dislocations, doubly charged* V_{Ga} *acceptor complexes with oxygen as well as nitrogen interstitials was confirmed.*

Keywords DLTS, AlGaN/GaN HEMT, defects

1. INTRODUCTION

GaN-based high electron mobility transistors (HEMTs) are very attracted candidates for 5G network applications due to their usage in high output power amplifiers: millimetre-wave frequencies [1]. The continuous research effort is devoted to improving the cost-effectiveness and performance of microwave devices [2]. Improving the device frequency performances requires decreasing the gate length to diminish the transit time. Short channel effects are, therefore, a major challenge to achieve simultaneously high current density, high transconductance, low series resistance, and high bias operations [3].

The gate-lag effect in HEMTs has been reduced strongly by passivation and field plate [4, 5]. The introduction of the field plate is effective in reducing the lag and current collapse when the acceptor density in the buffer layer is high, because electron trapping in the buffer layer occurs near the heterojunction interface in this case and, hence, the field plate can weaken this trapping under the gate because of reduction in the electric field at the drain edge of the gate [6]. With the excellent ability of these field plate techniques to effectively extend the depletion region and replace a single-peak electric field with several peaks, the electric field distribution could be uniformed, the device breakdown performance and other relevant reliability performance, such as trapping effect, the inverse piezoelectric effect could be improved [7, 8].

This paper aims to report results of a defect analysis, carried out on AlGaN/GaN HEMT heterostructures grown on SiC substrate with gold source-connected field-plate by the Deep Level Transient Fourier analysis (DLTFS) method [9].

2. EXPERIMENTAL

The investigated samples, the AlGaN/GaN HEMT structures with gold source-connected field-plate, were prepared by the MOCVD process on SiC (Fig. 1a). The number of gate fingers is eight (length $L_g \cong$ <0.2 µm, width w_g = 100 µm, SD ~3 µm). Fig. 1b display characteristic C-V curves measured on the investigated HEMT in connection Drain-Source, Gate-Source and Gate-Drain at temperature 300 K. Measured Current-Voltage characteristics of Schottky barrier and output HEMT characteristics are shown in Fig. 2.

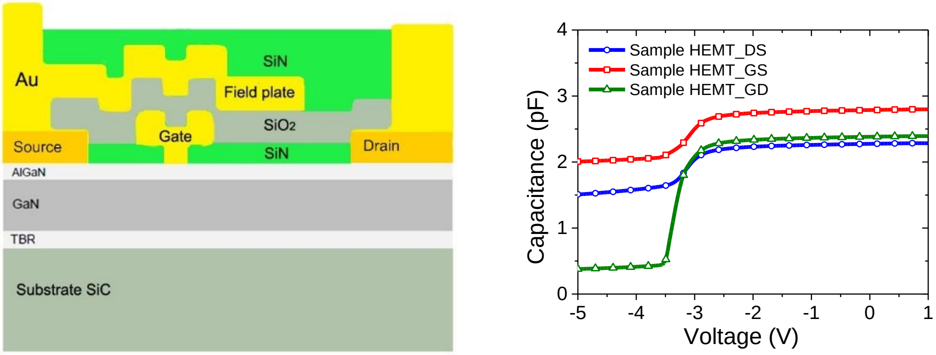

Fig. 1 a) Schematic description of the layer structure of investigated samples,
b) Comparison of Capacitance - Voltage characteristics for investigated HEMT in connection Drain-Source, Gate-Source and Gate-Drain.

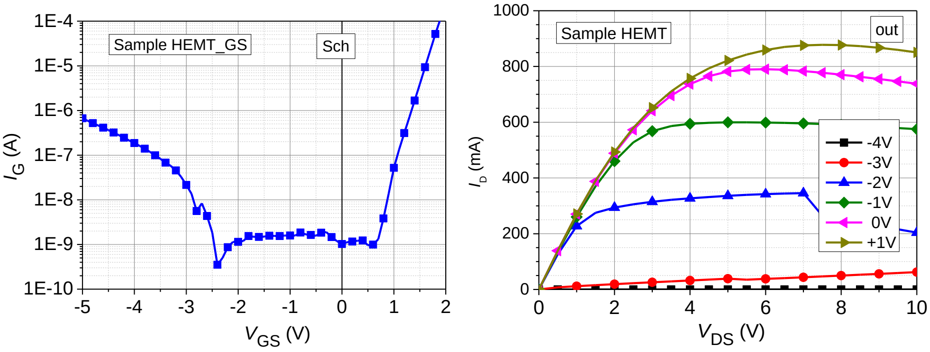

Fig. 2 Measured Current-Voltage characteristics of Sample HEMT.

All measurements of DLTFS study were performed using measurement system BIO-RAD DL 8000 DLTS on Institute of Electronics and Photonics. The signal frequency for capacitance measurements is 1 MHz, and the magnitude of the applied differential voltage is 30 mV. The DLTFS measurements in the temperature range from 80 to 550 K. The obtained DLTFS spectra were evaluated by Direct Arrhenius Analysis. The basic parameters of deep energy levels (activation energy ΔE_T (eV) and capture cross-section σ_T (cm^2) were calculated from obtained Arrhenius plots [9].

3. RESULTS AND DISCUSSION

The evaluation of the measured DLTS spectra had shown the existence of several deep energy levels in the measured structures. Fig. 3 and Fig. 4 depict measured DLTFS spectra under the different measurement conditions (drain-source DS, gate-source GS) with evaluated 11 deep energy levels with their activation's energies and positions in the spectra.

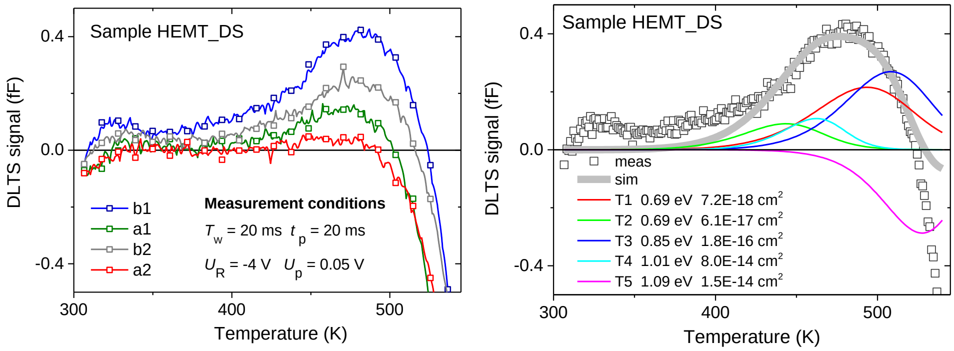

Fig. 3 DLTFS study results Sample HEMT_DS.

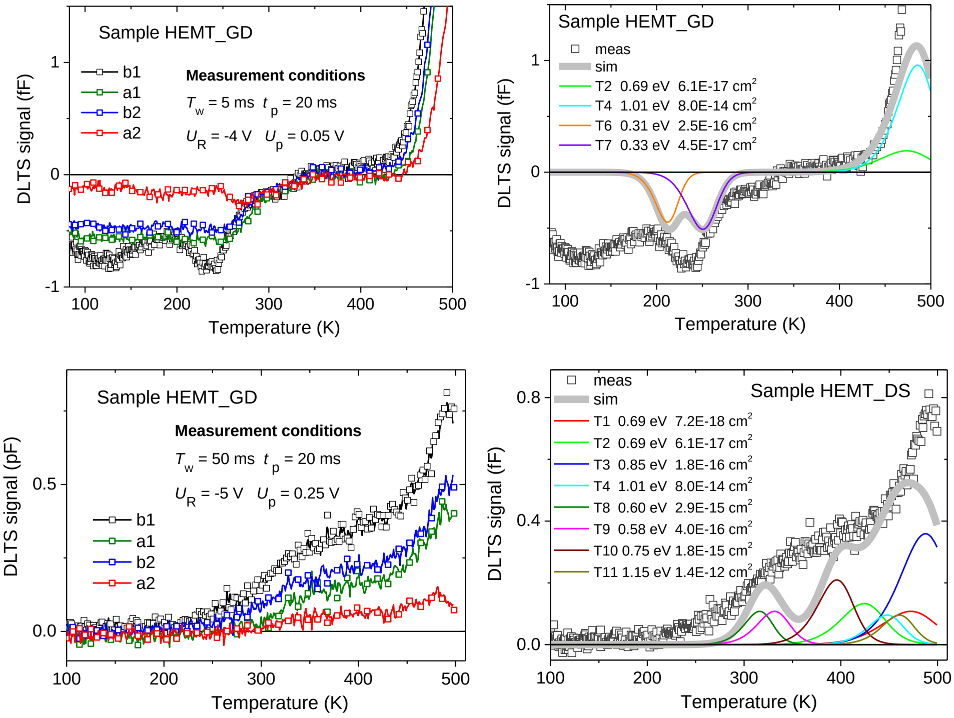

Fig. 4 DLTFS study results Sample EMT_GD.

The electron-like traps T1, T2 (0.69 eV) are probably associated with N_{Ga}-related defect and Nitrogen antisite, traps T3 (0.85 eV) and T10 (0.75 eV) could be related to Nitrogen interstitials, traps T4 (1.01 eV) correspond to threading dislocations, traps T8 (0.60 eV) and T9 (0.58 eV) could be related to the linear array of defects due to dangling bonds along edge dislocations, and T11 (1.15 eV). The hole-like energy levels T5 (1.09 eV), probably correspond to the stable doubly charged V_{Ga} acceptor complexes with oxygen donors $(V_{Ga}–O)^{2-}$, traps T6 and T7 (0.31, resp. 0.33 eV) could be related to the barrier [10, 11].

4. CONCLUSION

This work deals with a DLTFS investigation of defect distribution in AlGaN/GaN HEMT heterostructure with gold source-connected field-plate prepared by the MOCVD process on SiC substrates. Parameters of 11 defect states (8 electron-like states and three hole-like states) were identified. The presence of N_{Ga}-related defect, screw dislocations, doubly charged V_{Ga} acceptor complexes with oxygen as well as a nitrogen intersticials was confirmed. The investigated structures are of high quality, hence only well-known structural defects with low concentrations were identified.

Acknowledgement

This work has received funding from the ECSEL JU under grant agreement No 783274, project 5G_GaN2. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and France, Germany, Slovakia, Netherlands, Sweden, Italy, Luxembourg, Ireland. The work was also supported by the Slovak Scientific Grant Agency VEGA (contract VEGA 1/0668/17) and by the Slovak Research and Development Agency (project SK-PL-18-0068).

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