Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 140-141

F-2-5

Drain Current DLTS of AlGaN/GaN MIS-HEMTs

T. Okino, M. Ochiai, Y. Ohno, S. Kishimoto, K. Maezawa, and T. Mizutani
Department of Quantum Engineering, Graduate School of Engineering, Nagoya University
Furo-cho, Chikusa-ku, Nagoya 464-8603 Japan
Phone: +81-52-789-5388, Fax: +81-52-789-5232 E-mail: t_okino@echo.nuee.nagoya-u.ac.jp

1. Introduction

AlGaN/GaN HEMTs have received much attention for high-frequency and high-power applications because of a high breakdown field in the wide-bandgap semiconductor. In order to fully develop the potential of the device, it is important to solve problems such as large gate leakage current [1,2] and drain current collapse [3-5], because they limit the RF performance of the device. We have recently reported that the gate leakage current and current collapse were suppressed in AlGaN/GaN MIS-HEMTs with a Si_3N_4 gate insulator [6]. It is important to understand the transient behavior of the devices to apply them to the real systems. DLTS is one of the most powerful techniques to study the transient behavior caused by deep levels. Capacitance DLTS is often used to characterize the crystal quality. However, it is important to directly study the transient behavior of the device to understand the effects of the deep levels on the device performance. We have recently studied the transient behavior of AlGaN/GaN HEMTs by the drain current DLTS, where surface-state related levels were observed in the DLTS signal. In this report, we studied the transient behavior of AlGaN/GaN MIS-HEMTs by the current DLTS.

2. Experiments

Figure 1 shows schematic cross section of the fabricated AlGaN/GaN MIS-HEMTs with Si_3N_4 gate insulator. The epitaxial layer structure is i-AlGaN (3 nm)/n-AlGaN (7 nm, 6×10^{18} cm^{-3})/i-AlGaN (3 nm)/i-GaN (3 μm)/i-AlN (40 nm). The AlN mole fraction of the AlGaN layers is 0.3. Si_3N_4 gate insulator (10 nm) was deposited by ECR sputtering after the ohmic contact formation. Si_3N_4 serves simultaneously as a gate insulator and a surface passivation film. Reference device without Si_3N_4 gate insulator was also fabricated. The gate length (L_G) was 1.5 μm and the threshold voltage was about -8 V. A voltage pulse (voltage amplitude of 4 V with peak voltage of 1 V and the pulse width of 10 ms) was applied to the gate of the device at V_{DS}=8 V, and the drain current transient was measured by DLTS technique, as shown in Fig 2.

Figure 3 and 4 show DLTS signal of AlGaN/GaN MIS-HEMTs and conventional HEMTs, respectively, as a function of temperature. There are two negative peaks, #A and #B, in the case of MIS-HEMTs, which correspond to the electron traps in the epitaxial layer. In the case of HEMTs on the other hand, there are three peaks, #1, #2, and #3. The hole-trap-like positive peaks #1 and #3 were attributed to capture and emission of the electrons injected from the gate electrode at the surface states [7]. It is notable that the surface-state-related positive peaks were not observed in the MIS-HEMTs, which indicates that the Si_3N_4 gate insulator serves also as a passivation film. It is worth while to note that the negative peak #A in the MIS-HEMTs was observed at same temperature as peak #2 in the HEMTs, which suggests that the peaks #A and #2 are caused by same trap. Figure 5 shows the Arrhenius plots of $T^2\tau$ for these peaks. Triangles are for the MIS-HEMTs and circles are for the HEMTs. Closed symbols are for the negative peaks and open symbols are for the positive peaks. The activation energies (E_a) of the peaks were #A:0.49 eV and #B:0.62 eV for the MIS-HEMTs, and #1:0.29 eV, #2:0.61 eV and #3:0.55 eV for the HEMTs. Solid line is related to defects in GaN reported by Hacke et al. [8]. The peaks #A and #2 are plotted at the position close to the solid line. We interpret the peaks #A and #2 as corresponding to the electron trap originating from the defect level in GaN. The electron trap #B, which is observed only in the MIS-HEMTs, may be due to the damage caused by Si_3N_4 deposition. The suppression of the damage will be a subject of further investigation.

3.Summary

Transient behavior of AlGaN/GaN MIS-HEMTs were studied by drain current DLTS study. The electron traps, which probably originate from the defect level in GaN and from the damage caused by Si_3N_4 deposition, were observed. Hole-trap-like positive peaks which are related to the surface states are suppressed in the AlGaN/GaN MIS-HEMTs.

References

[1] X. Hu, A. Koudymov, G. Simin, J. Yang, M. Asif Khan, A. Tarakji, M. S. Shur and R. Gaska, Appl. Phys. 79 (2001) 2832.
[2] S. Mizuno, Y. Ohno, S. Kishimoto, K. Maezawa and T. Mizutani, J. Appl. Phys. 41 (2002) 5125.
[3] R. Vetury, N. Zhang, S. Keller, and U. Mishra, IEEE Trans. Electron Devices 48 (2001) 560.
[4] A. Tarakji, G. Simin, N. Ilinskaya, X. Hu, A. Kumar, A. Koubymov, J. Yang and M. A. Khan, Appl. Phys. 78 (2001) 2169.
[5] T. Mizutani, Y. Ohno, M. Akita, S. Kishimoto, and K. Maezawa, phys. stat. sol. (a) 194 (2002) 447.
[6] M. Ochiai, Y. Ohno, S. Kishimoto, K. Maezawa, and T..Mizutani, JJAP 42 (2003) 4B (to be published).
[7] T. Mizutani, T. Okino, K. Kawada, Y. Ohno, S. Kishimoto, and K. Maezawa, ICNS-5, May 26-30, 2003, Nara, Japan
[8] P. Hacke, T. Detchprom, K. Hiramatsu, N. Sawaki, K. Tadatomo, and K. Miyake, J. Appl. Phys. 76 (1994) 304.

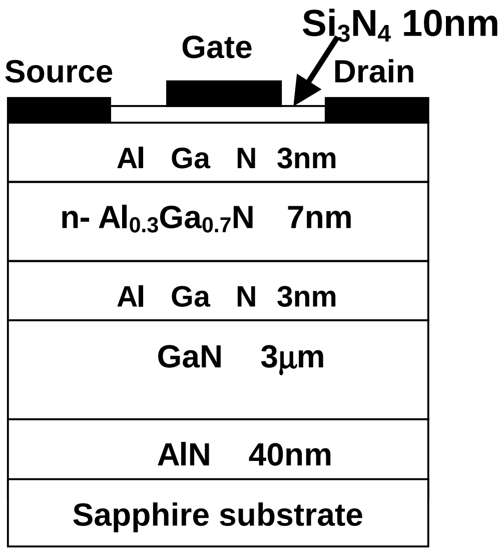

Fig.1 Schematic cross section of the fabricated AlGaN/GaN MIS-HEMTs.

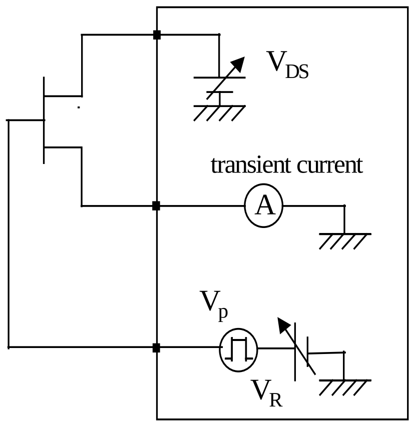

Fig.2 Drain current DLTS system.

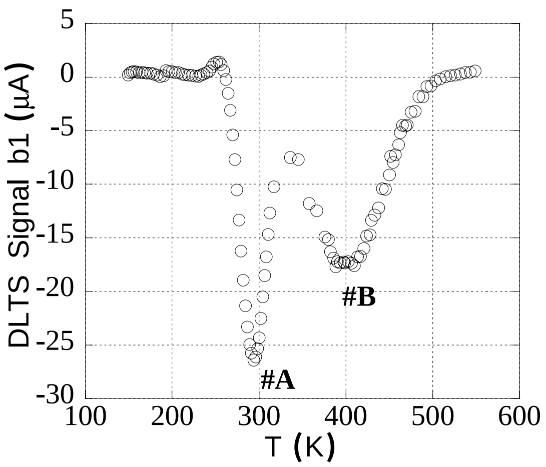

Fig.3 Typical drain current DLTS spectrum for 1.5-μm gate AlGaN/GaN MIS-HEMTs.

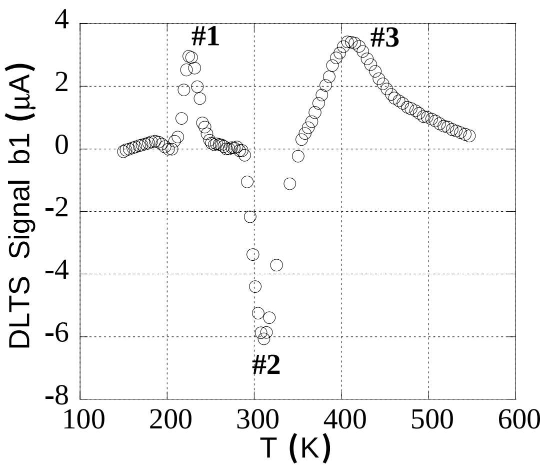

Fig.4 Typical drain current DLTS spectrum for 1.5-μm gate AlGaN/GaN HEMTs.

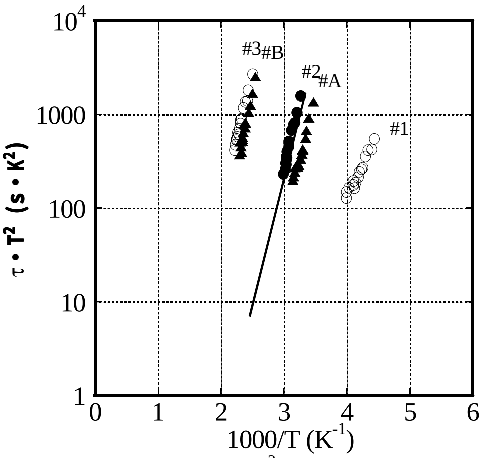

Fig.5 Arrhenius plots of $T^2\tau$ for MIS-HEMTs (triangles) and HEMTs (circles). Closed symbols are for the negative peaks and open symbols are for the positive peaks, respectively. Solid line is the result reported by Hacke et al.