Electrostatic Discharge Effects in AlGaN/GaN High-Electron-Mobility Transistors

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Devices may face electrostatic discharge events during manufacturing, handling, or device operation. Typical current pulses are in the ampere range with durations between nanoseconds and microseconds. These transient conditions may facilitate high-current pulses before thermal runaway terminates device functionality. The importance of failure mechanism study in III-nitride transistors is given by their usage as power devices in many defense and commercial applications where harsh environment conditions are expected.

100 ns long rectangular current pulses using a transmission line pulser (TLP) were used for stressing of the HEMT drain contact. The pulsed *I-V* characteristics were extracted using a digital oscilloscope. We used backside interferometric mapping technique to localize current path (dissipated power) in HEMTs during the TLP stress. The mapping was performed using an infrared laser beam scanning the device from the backside (3 ns time, 1.5 µm space resolution).

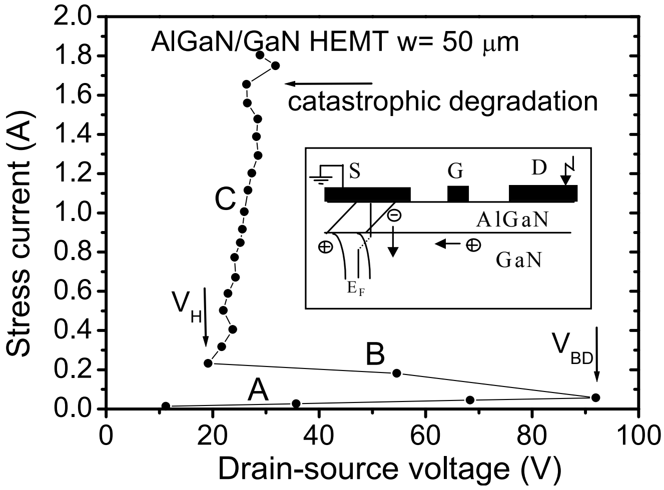

Fig. 1: Typical drain-source high current pulsed *I-V* curve of AlGaN/GaN HEMT. The inset illustrates the band diagram and assumed process of the hole accumulation and electron injection into the GaN buffer; after [1].

The measured drain-source high-current pulsed *I-V* characteristics exhibit S-shape with three regions [1] (see Fig. 1): A low-current/ high-impedance region A, a NDC region B, and a high-current/ low-voltage region C. The triggering voltage V_{BD} of the source-drain breakdown is 62 – 98 V for all measured devices and the holding voltage V_H ~20 V. When a critical current stress level of 1.65 A is reached, the device catastrophically degrades (see arrow in Fig. 1). The device's DC transfer characteristics taken prior and after current stresses (below the catastrophic degradation level) are presented in Fig. 2. The pulsed operation of the HEMT in regions B and C causes a shift of the threshold voltage upwards, from the nominal value of V_T = –0.9 V to the value of V_T = ~ -0.4 V (Fig. 2). Simultaneously the value of the Schottky contact built-in voltage was found to be unchanged. These together with the fact that the VT shift has been observed to be reversible let us assume that the electron trapping at the buffer side of the buffer-channel interface occurs after the HEMT is triggered.

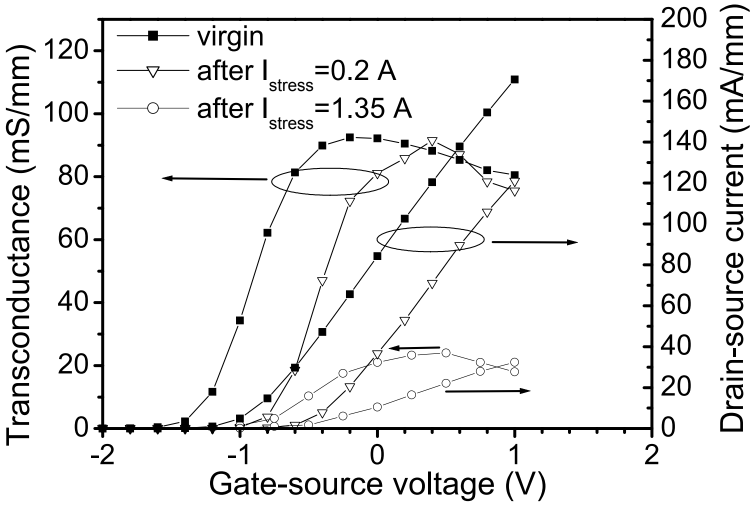

Fig. 2: Transconductance and drain current transfer characteristics of AlGaN/GaN HEMT (at drain voltage 8 V) before and after selected stress pulses; after [1].

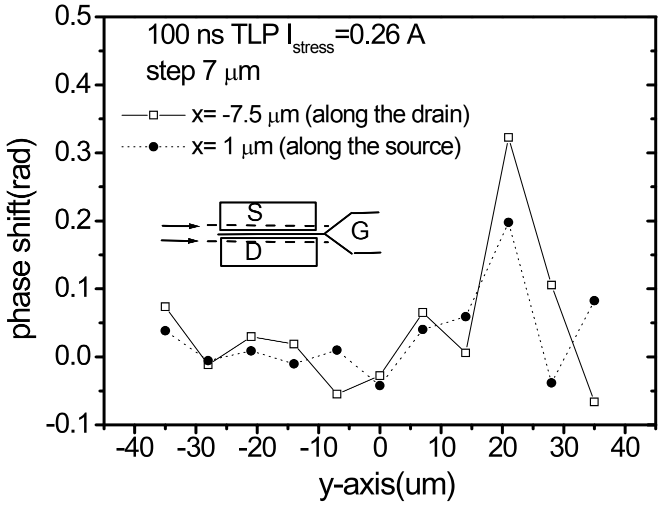

Fig. 3: Measured distribution of phase shift at t = 100 ns in AlGaN/GaN HEMT along the source and drain at I_{stress} = 0.26 A. The HEMT active region spans from y = –25 to y = 25 μm; after [1].

Figure 3 shows the phase shift (i.e. drain current) distribution as a function of position along the device width. The device was scanned along the drain and source contacts with steps of 7 μm at I_{stress} = 0.26 A (region C). A phase peak is found at the right edge of the HEMT channel, indicating the current filamentation. This shows that the transition into the low-voltage/high-current region is followed by the current filament formation. Such a behavior is typical for current-controlled systems with NDC.

If we accept theoretical model of GaAs FETs [2] our observation of NDC and filamentation in the AlGaN/GaN HEMT may be linked to the avalanche-injection processes in the buffer layer (see inset of Fig. 1). The measured V_T shift, explained by the electron trapping in the buffer, supports this model. The decisive role of the buffer layer in the breakdown mechanism was also predicted by the theoretical model [2] showing that no NDC can be expected if the buffer layer is omitted. However, III-nitrides represent an unconventional material system, and other physical mechanisms cannot be ruled out completely.

References

[1] J. Kuzmík, D. Pogany, E. Gornik, P. Javorka, P. Kordoš, Applied Physics Letters, **83,** 4655 (2003).

[2] V. A. Vashchenko, N. A. Kozlov, Y. B. Martynov, V. F. Sinkevitch, and A. S. Tager, IEEE Transaction on Electron Devices **43**, 513 (1996).