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Dynamic Current Collapse in Lateral GaN Schottky Diodes

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Nitride-based devices have become leading contenders for high voltage power applications due to their very favorable characteristics [1]. AlGaN/GaN lateral High Electron Mobility Transistor (HEMT) devices are at the most mature level due to early adoption in RF/MW applications. If configured as a diode, this structure can potentially provide low turn-on voltage due to the Schottky diode and low forward on-resistance due to the high 2DEG density and high mobility of the quantum well. An arbitrarily high reverse breakdown voltage can be achieved by scaling the anode (gate) to cathode (source/drain) distance, with the potential tradeoff with the forward resistance. All these characteristics are highly desirable for high voltage power conversion applications. However, dynamic switching response is important for this application and a potential concern because of well-known trap related transient effects in this material system [2].

AlGaN/GaN lateral diodes of peripheries from 0.4 to 2mm and 10 to 100µm anode to cathode distances were fabricated. These devices showed excellent forward on-resistances of 67Ω/mm and breakdown voltages (> 9000V for 100um gap devices), under DC operations, but failed at a high rate during fast switching experiments. To investigate the root cause of this failure, a physics-based TCAD model was developed and calibrated to measured DC response. The pulsed simulation results replicated the observed slow, reverse bias dependent current recovery following fast turn-on and traced current collapse to the carbon doping below the channel. Since GaN is semi-insulating, it is necessary to dope the buffer with deep-level acceptor type dopants. During reverse bias, the carriers transitions from the channel to the carbon doping centers. After pulsed forward bias, the carriers are unable to return to channel quickly because of the energy required to overcome the energy barrier and gets released slowly via a thermal process. This channel charge recovery time depends on the doping level and the distance of the doping from the channel. This study demonstrated that the buffer doping plays a critical role on the reverse recovery characteristics and can limit the maximum reverse voltage operation of a GaN lateral diode. A carefully designed DOE of buffer doping against the need of breakdown voltage rating, operating frequency and leakage current is required.

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References

[1] J. Millán, P. Godignon, X. Perpiñà, A. Pérez-Tomás and J. Rebollo, IEEE Trans. Power Electron. **29**(5), 2155 (2014).
[2] R. Vetury, N. Q. Zhang, S. Keller and U. K. Mishra, IEEE Trans. Electron Devices **48**(3), 560 (2001)

Supplementary information

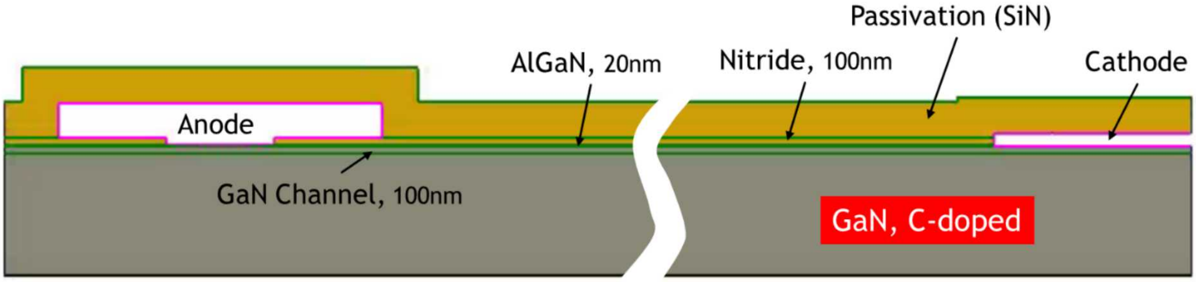

Figure 1: Model representation of the device structure

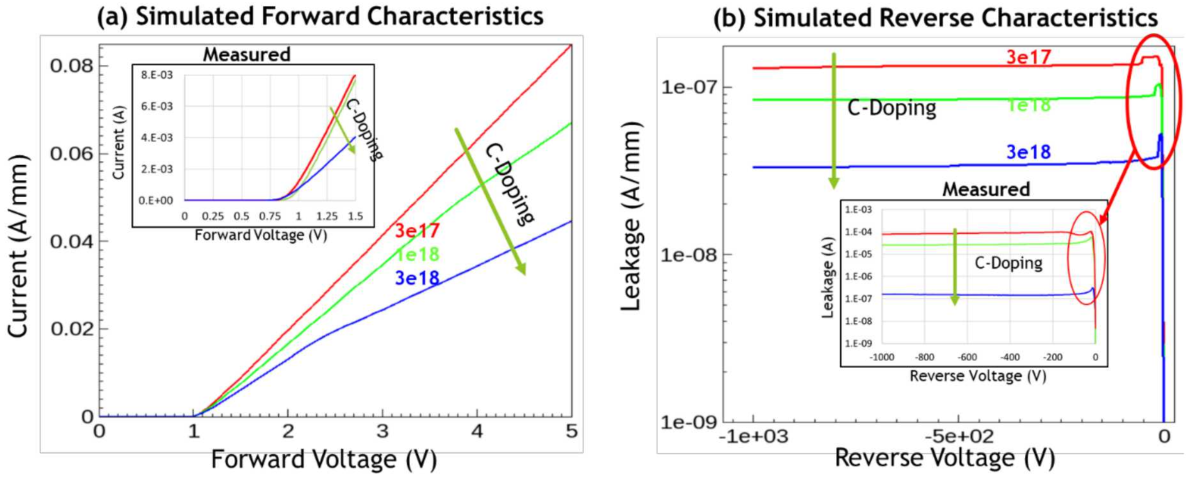

Figure 2: Measured and modeled DC (a) forward and (b) reverse characteristics (circled regions comparing the measured and modeled voltage leakage characteristics).

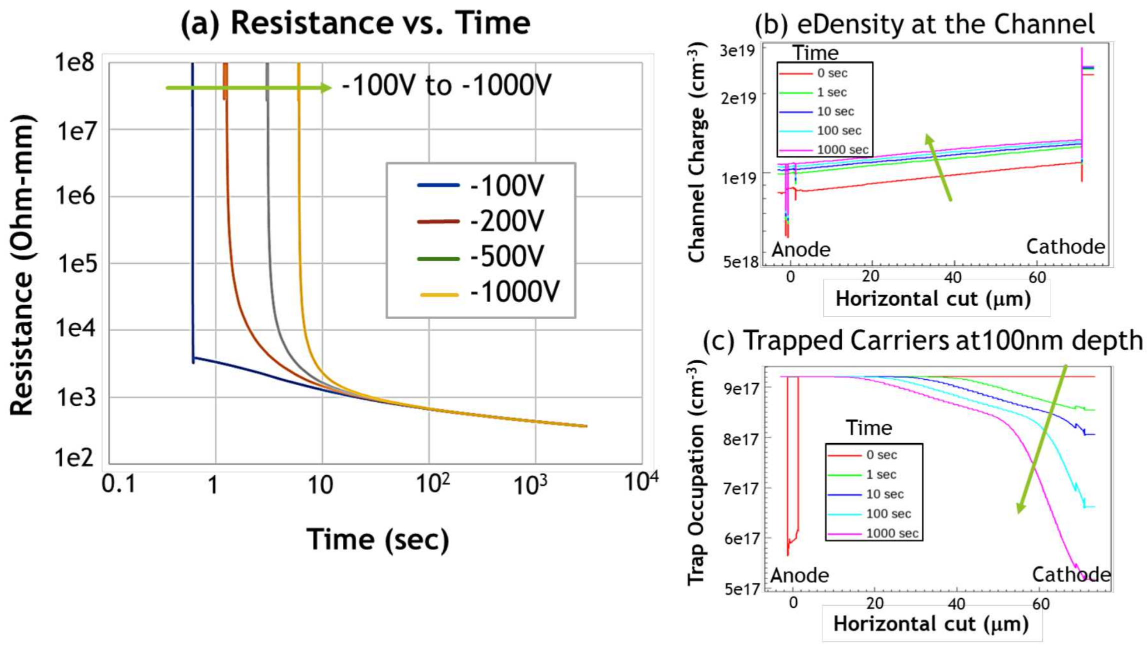

Figure 3: (a) Resistance change during forward bias for different pulsed reverse bias levels. The corresponding (b) electron density and (c) trap densities show the slow charge transfer from the carbon traps to the channel over time.