

# Reliability-Oriented TCAD Modelling of Low-Voltage Schottky p-GaN Gate Power HEMT Using $C_{RSS}(V_{DS})$ Curve as a Relevant Trapping Diagnosis

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## SUMMARY

p-GaN gate HEMTs have emerged as promising wide-bandgap devices for power applications due to their normally-off operation and superior switching performances. However, their reliability remains strongly affected by trapping phenomena and high-electric-field stresses occurring during hard-switching and reverse conduction operations. Understanding these mechanisms requires accurate physical models capable of reproducing both static and dynamic electrical behaviors of the device.

This work presents a TCAD calibration methodology applied to a commercial p-GaN gate HEMT. The proposed approach relies on a semi-empirical and experience-driven parameter adjustment strategy, enabling the extraction of a physically consistent parameter set while maintaining good agreement with experimental measurements. The fitting procedure is validated through comparison between simulations and measurements of several electrical characteristics, including transfer characteristics  $I_{DS}(V_{GS})$ , output characteristics  $I_{DS}(V_{DS})$ , gate capacitance  $C_{GS}(V_{GS})$ , and output capacitances  $C_{RSS}(V_{DS})$  and  $C_{OSS}(V_{DS})$ . The obtained results show good agreement with both the experimental results and the datasheet.

Using the calibrated TCAD model, a trapping sensitivity study was carried out to investigate the impact of fixed charges on the  $C_{RSS}(V_{DS})$  characteristic under realistic operating conditions. Experimental hard-switching stresses performed in half-bridge operation revealed a rightward shift of the  $C_{RSS}(V_{DS})$  knee voltage, attributed to the generation of positive trapped charges beneath the field plate region (Fig.1 a)). Conversely, reverse conduction stresses produced a leftward shift, associated with negative charge trapping induced by hot electron injection through the AlGaIn barrier (Fig.1 b)).

Dedicated TCAD simulations were then performed to reproduce these experimental behaviors. The introduction of positive fixed charges at the AlGaIn/GaN interface increased the 2DEG density and shifted the  $C_{RSS}(V_{DS})$  characteristic toward higher drain voltages, while negative charges reduced the 2DEG density and produced the opposite effect (Fig.2). The simulations showed good agreement with experimental observations and confirmed the strong correlation between  $C_{RSS}(V_{DS})$  knee evolution and charge trapping mechanisms.

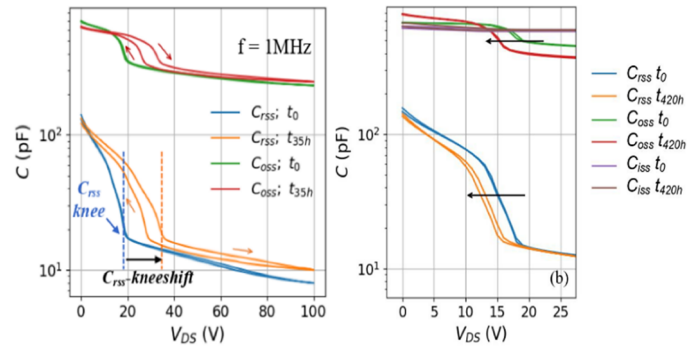


Fig.1 a)  $C_{RSS} = f(V_{DS})$  and  $C_{OSS} = f(V_{DS})$  under a 67 V stress condition. The main change to be observed is the  $C_{RSS}$  knee shift, b) Observation of a shift of the capacitance knee.

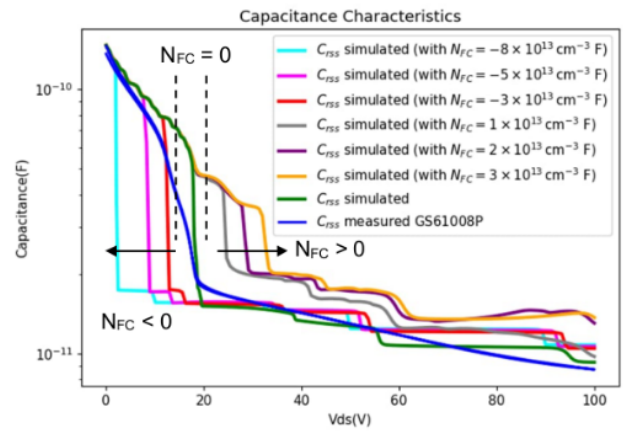


Fig.2. Simulated  $C_{RSS}(V_{DS})$  characteristics for different positive and negative fixed charge densities  $N_{FC}$ , compared with reference curve.

Overall, the proposed methodology provides a robust and physically consistent TCAD fitting approach for commercial p-GaN HEMTs. The study also demonstrates that the  $C_{RSS}(V_{DS})$  characteristic constitutes an efficient diagnostic marker for the localization, identification, and characterization of trapped charges in p-GaN devices subjected to switching stresses.