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# GaN-based power HEMTs, Parasitic, Reliability and high field issues

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**Abstract and Goal –** With this paper we present an overview of the parasitic mechanisms that limit the performance of power HEMTs, which are characteristic of the high electric fields reached by these devices during operation. More specifically, we describe the following phenomena: *(i)* long-term trapping of electrons in the gate-drain access region, with subsequent modification in the static and dynamic value of Ron; *(ii)* the degradation of the gate junction, due to a defect generation/percolation process which occurs at high reverse bias; *(iii)* the degradation of HEMTs due to hot-electron related phenomena.

**Experimental Details –** The test were carried out on AlGaN/GaN HEMTs with both silicon and silicon carbide substrate. Before any stress test, devices were submitted to static and dynamic characterization, with the aim of investigating the trapping processes that occur at high $V_{DS}$ levels (up to 100 V). Stress tests were then carried out, both in reverse (off-state) conditions, and in on-state. During stress, devices were characterized by means of electrical and optical (EL) investigation.

**Results and Discussion –** Static and dynamic investigation of the trapping phenomena indicated, in the analyzed devices, the existence of long-term trapping/detrapping kinetics: when submitted to high $V_{DS}$ levels, devices can show a significant decrease in the drain current. By combined pulsed investigation and dynamic Ron analysis this effect was attributed to a significant trapping of electrons in the gate-drain access region, with subsequent increase in the on-resistance of the samples. Details on the trapping/detrapping kinetics and activation energies will be presented in detail during the conference.

By means of stress tests carried out in off-state conditions we analyzed the degradation of HEMTs submitted to reverse-bias: results of constant-voltage stress tests indicated that, for moderate stress voltage levels, degradation proceeds through a defect generation and percolation process: this is a gradual degradation mechanism, which is significantly different from the converse-piezoelectric effect (usually quoted as a possible cause for reverse-bias degradation). A detailed analysis of the degradation kinetics was obtained through combined electrical, optical and capacitive investigation.

Stress tests in on-state conditions were carried out on devices with high robustness towards high reverse bias. Results indicate that, when HEMTs are submitted to high drain voltage levels in on-state, they can show a remarkable and gradual decrease in drain current. Results of the stress tests support the hypothesis that degradation is due to hot-electron effects: at high gate-drain voltages, electrons may achieve high energy, and be trapped in the SiN passivation, in the AlGaN barrier, and/or in the SiN/surface interface. Degradation rate strongly depends on the amount of hot electrons that are present in the channel, which can be quantified by means of EL measurement: a degradation law for hot-electron induced degradation was extrapolated based on the results of EL and electrical measurements.

## References

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