School of Electrical, Computer and Energy Engineering

PhD Final Oral Defense
Modeling Reliability of Gallium Nitride High Electron Mobility Transistors

by
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Abstract
This work is focused on modeling the reliability concerns in GaN HEMT technology. The two main reliability concerns in GaN HEMTs are electromechanical coupling and current collapse. A theoretical model was developed to model the piezoelectric polarization charge dependence on the applied gate voltage. As the sheet electron density in the channel increases, the influence of electromechanical coupling reduces as the electric field in the comprising layers reduces.

A Monte Carlo device simulator that implements the theoretical model was developed to model the transport in GaN HEMTs. It is observed that with the coupled formulation, the drain current degradation in the device varies from 2%-18% depending on the gate voltage. Degradation reduces with the increase in the gate voltage due to the increase in the electron gas density in the channel. The output and transfer characteristics match very well with the experimental data.

An electro-thermal device simulator was developed coupling the Monte Carlo-Poisson solver with the energy balance solver for acoustic and optical phonons. An output current
degradation of around 2-3% at a drain voltage of 5V due to self-heating was observed. It was also observed that the electrostatics near the gate to drain region of the device changes due to the hot spot created in the device from self-heating. This produces an electric field in the direction of accelerating the electrons from the channel to surface states. This will aid to the current collapse phenomenon in the device. Thus, the electric field in the gate to drain region is very critical for reliable performance of the device. Simulations emulating the charging of the surface states were also performed and matched well with experimental data.

Methods to improve the reliability performance of the device were also investigated in this work. A shield electrode biased at source potential was used to reduce the electric field in the gate to drain extension region. The hot spot position was moved away from the critical gate to drain region towards the drain as the shield electrode length and dielectric thickness were being altered.