Electrically-Induced Changes in Threshold Voltage and Source Resistance in RF Power GaAs PHEMTs

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GaAs Pseudomorphic High-Electron Mobility Transistors (PHEMTs) have great potential for RF power applications. A major issue with these devices is electrical reliability—the gradual degradation of certain electrical characteristics that occur under prolonged high-voltage biasing. The degradation of the extrinsic drain (observed via an increase in the drain resistance $R_D$ and a decrease in the maximum drain current $I_{max}$) is usually of primary concern; however, under high-bias stress, significant shifts in the threshold voltage $V_T$ and in the source resistance $R_S$ are also observed. Since such changes affect the long-term electrical performance of the device, it is important to understand the underlying mechanisms behind these changes.

In our study, experimental RF power PHEMTs were electrically stressed using a bias-stressing scheme that kept the impact-ionization rate constant [1]. During stressing, the devices were characterized at frequent intervals. In our experiments, we observed negative shifts in $V_T$ (Figure 1) and decreases in $R_S$ (Figure 2), which were both accelerated with increasing temperature. Both the changes in $V_T$ and $R_S$ tended to saturate with stressing and could be modeled well by an exponential fit. Additional tests showed that the $V_T$ shift was recoverable with unbiased storage at room temperature. This makes $\Delta V_T$ consistent with a trapped electron recombination mechanism occurring under the gate, as previously identified in [2]. In this mechanism, the trapped electrons recombine with holes generated from impact ionization on the drain side of the device. As for $R_S$, through additional experiments on simple test structures, we were able to attribute the decrease in $R_S$ to an increase in sheet carrier concentration ($n_s$) on the source. This suggests the presence of a similar electron-trapping and recombination mechanism on the source side. All these findings provide a better understanding of the cause for these device instabilities and thus, should be instrumental in developing effective solutions to this problem.

Figure 1: Time evolution of the threshold voltage shift of GaAs PHEMTs stressed at $I_D=400$ mA/mm, and $V_{DS}+V_T = 6.0$ V, at 25, 50, and 75°C in $N_2$. Solid lines show exponential fits to data.

Figure 2: Time evolution of the source resistance decrease of GaAs PHEMTs stressed at $I_D=400$ mA/mm, and $V_{DS}+V_T = 6.0$ V, at 25, 50, and 75°C in $N_2$. Solid lines show exponential fits to data.

REFERENCES:
