The Optimization of T-shape Gate Geometry in GaN HEMTs by Monte Carlo Simulation

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In recent years, there is a growing demand for GaN based high electron mobility transistors (GaN-HEMTs) to operate at high frequency toward terahertz range (300GHz - 30THz). However, the bottle-neck to hinder this advance is the low breakdown voltage caused by the electric field peaks existing at the gate-foot and shoulder-edge near the drain side. When the gate length (L_g) is further shrunk down to sub 100 nm, the uneven distribution of electric field in channel layer of the HEMTs becomes more serious, so that the device could be easily breakdown at lower bias. It is believed that the electric field distribution should be efficiently controlled by the gate geometry, especially when the gate length is below 100 nm. In this work, we have carried out the systematic research on the relationship between the gate geometry and the DC/RF performance for fixed GaN based layer structure (Figure 1) by Monte Carlo simulation. The foot-length and the foot-height are carefully optimized to achieve high breakdown voltage and high current cut-off frequency.

Figure 1(a) presents the fabricated T-shape gate for GaN-HEMT. Figure 1(b) schematically depicts the diagram for the device structure. The ratio of foot-height/gate length is defined as α. Figure 2(a) shows the simulated distribution of the lateral electric field in the channel layer in off-state when V_d is set to be 60V. As the increase of the gate height, the peak electric field at the gate foot goes higher, but that at the head edge decreases, indicating the optimal α should be around 1.5. Figure 2(b) illustrates the relationship between α and the peak electric field at the gate foot. Figure 3(a) presents the RF characteristic of GaN HEMT with different foot heights. To find out the optimal ratio of gate height to gate length, a relationship between α and cut-off frequency was simulated, as shown in Figure 3(b).When the gate length decreases from 200 nm to 100 nm, the frequency goes higher, but when the gate length reduces continuously, the frequency drops slightly because of the short channel effect. Based on the overall simulation, the optimized relation between gate length and foot-height can be obtained in gate geometry design.

In summary, the geometry of T shape gate regarding the gate-length and the foot-height have been optimized which the gate length should be around 50 nm and the optimum ratio of foot-height/gate-length should be around 1.5. GaN-HEMT with this gate structure can achieve both a high cut-off frequency and a high breakdown voltage. This work offers a promising solution to the bottle-neck of high frequency operation in GaN-HEMTs for power amplifiers in both micro- and terahertz-wave communications.

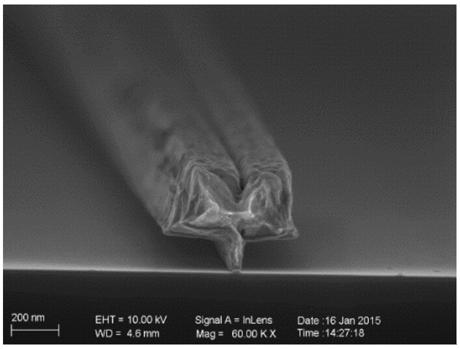

Figure 1(a) fabricated T-shape gate for GaN-HEMTs

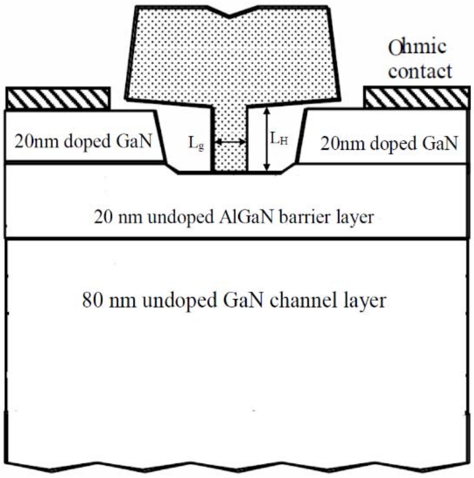

Figure 1(b) structure of the designed GaN HEMTs

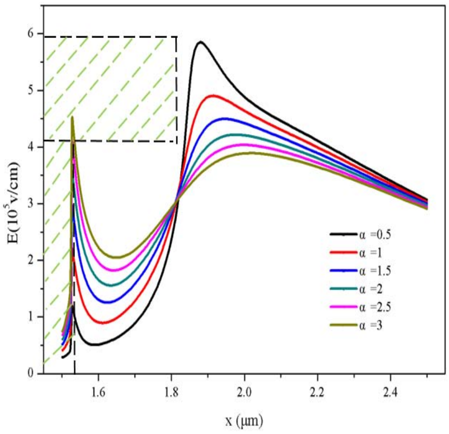

Figure 2(a) lateral electric field distribution from 1.5μm to 2.5μm

for device with different gate heights

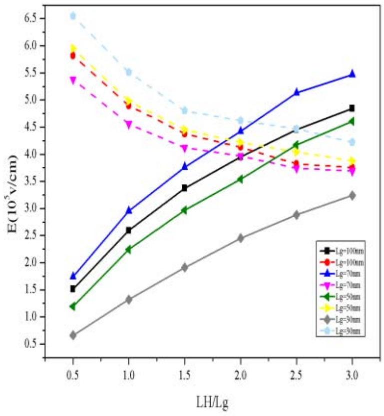

Figure 2(b) the relationship between α

and two peak electric fields in the channel

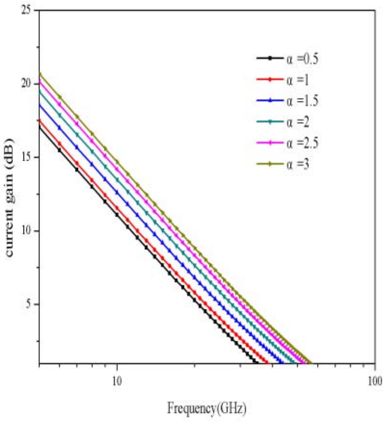

Figure 3(a) the device cut-off frequency with different

gate heights.

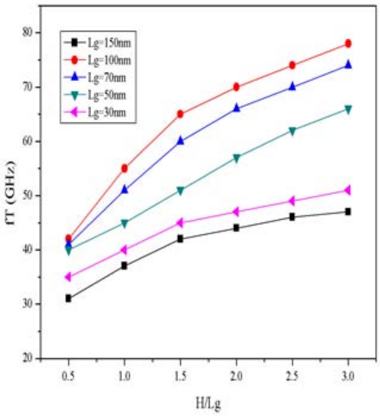

Figure 3(b) the relationship between α

and cut-off frequency