Performance of 15 nm Gate Length In\textsubscript{0.17}Al\textsubscript{0.83}N/GaN HEMT Used Simulation SILVACO Software.

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Abstract--We have simulated HEMT 15 nm length gate with ability in analysis DC, AC, Transit and high frequency characteristics. This work is the demonstration of motivation for HEMT with InAlN/GaN structure in different characteristics. The simulated HEMT devices with length gate 15 nm and materials InAlN show very good scalability. We have excellent exhibit $g_{m}=0.85S/\mu \text{m}$, $I_{DSS}=0.59A/\mu \text{m}$, $V_{TT}=120V$. The $L_{g}=15 \text{ nm}$ devices also feature record high-frequency characteristics for HEMT design with $f_{t}=875 \text{ GHz}$ and $f_{m_{max}}=1.1 \text{THz}$. More significantly, the periphery oxide of the Gate suppresses leakage current when compared with equivalent normal HEMTs.

Keywords: HEMT, 15nm length gate, Silvaco, InAlN/GaN.

I. Introduction

The HEMT has demonstrated to be an excellent model system to study fundamental physics and technology for devices issues and to provide well calibrated and relatively parasitic-free device results to support the development of simulators that would allow us to chart the future of this technology. And InAlN/GaN structure in different characteristics. The simulated HEMT devices with length gate 15 nm and materials InAlN show very good scalability. We have excellent exhibit $g_{m}=0.85S/\mu \text{m}$, $I_{DSS}=0.59A/\mu \text{m}$, $V_{TT}=120V$. The $L_{g}=15 \text{ nm}$ devices also feature record high-frequency characteristics for HEMT design with $f_{t}=875 \text{ GHz}$ and $f_{m_{max}}=1.1 \text{THz}$. More significantly, the periphery oxide of the Gate suppresses leakage current when compared with equivalent normal HEMTs.

GaInN-based HEMTs have high breakdown voltage and don’t need protection circuit [1]. The first HEMTs were developed mostly for low noise applications like receivers [3, 4, and 5].
This is what currently limits the reduction in HEMT lateral dimensions. Supressing this, would allow us to scale the HEMT below 15 nm while preserving excellent RF characteristics. In this work, we demonstrated an the periphery oxide of the Gate HEMT design that mitigates forward gate leakage current by over two orders of magnitude and yields excellent characteristics.

II. Process Technology

Fig. 1 shows a cross section of epitaxial layer structure used in this work and a schematic of the simulated device structure. Our device features an InAlN/GaN heterostructure design where the periphery oxide Al$_2$O$_3$ of the Gate is a different with conventional designs. As a result, after a triple recess process [2], the doping layer is eliminated in the intrinsic device resulting in a doping-free InAlN Barrier. This gives rise to a conduction band shape for the barrier that, for the same sheet carrier concentration.

Table 1: Parameter used for simulation in HEMT.

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer</td>
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<td>nm</td>
</tr>
<tr>
<td>Channel</td>
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<td>38</td>
<td>nm</td>
</tr>
<tr>
<td>Barrier</td>
<td>$E_D$</td>
<td>12</td>
<td>nm</td>
</tr>
</tbody>
</table>

A. DC Characteristics of HEMT

Fig. 2 shows output characteristics of an HEMT with $L_G$ of 15 nm. The device exhibits excellent pinch-off and saturation characteristics.

Fig. 3 shows output characteristics of an HEMT with $L_G$ of 15 nm with Kink effect for temperature ambient. The device exhibits the variation of gate current with drain voltage shows a rise after stress but without abrupt growth in gate current at $V_{DS}$, kink. Both drain and gate currents recover to the fresh state, indicating no creation of traps. Therefore, the enhancement of the kink effect is probably due to the traps activated in the InAlN barrier layer.

Fig. 4 shows the transconductance and the Input characteristics of a 15 nm HEMT of a previously demonstrated n-type In$_{0.17}$Al$_{0.83}$N HEMT with a similar channel density and barrier thickness gate length, and other parameters in Table 1. The HEMT displays comparable subthreshold characteristics to the normal HEMT with a subthreshold swing of $V_T=0.74$V and $g_m$ of 0.75 S/µm at $V_{DS} = 2V$.

B. AC Characteristics of HEMT

Fig. 5 shows Gain current $H_21$ of HEMT with $L_G$ of 15 nm. The device exhibits excellent characteristics at low results in frequency to 880GHz.

Fig. 6 shows Max Gain Power of HEMT with $L_G$ of 15 nm. The device exhibits excellent characteristics at low results in frequency to 1.11THz.

Fig. 7 shows Unilateral Gain Power of HEMT with $L_G$ of 15 nm. The device exhibits excellent characteristics at low results in frequency to 1.161THz.

Fig. 8 shows in and out Power of HEMT with $L_G$ of 15 nm. The device exhibits excellent characteristics at out power results in frequency to 1.161THz.

Fig. 9 shows the on gain measurement result of a 40dB wide device when tuned for power. A power out of 3.5 W/mm was achieved along with 42 dB power gain. This increased power density was obtained at a reduced power out of 3.5 W, which is attributed to reduction of trapping effect due to improved epi quality and surface passivation. Since the trapping effect deteriorates with increased electric field or bias voltage for a specific device dimension, performance of the device as a function of bias voltage can be used as a valid measure of this phenomenon.

Fig. 10 shows the measurement results of the InAlN/GaN HEMTs under a wide voltage bias range from 0 V to 20 V for $V_{DS}$ and 0V to -5V for $V_{GS}$, where the tuning was for optimum efficiency. It is seen that a relatively flat PAE plateau of 35-39% was achieved throughout the wide voltage span, illustrating flexibility of power-supply requirement for various applications. Simultaneously high power density of 3.5 W/mm and PAE of 39 % were obtained at 20V bias. The ability to achieve a high PAE at such a high bias voltage confirms the reduction of trapping effect with these devices. Obtaining a high PAE simultaneously with high power is essential for system insertion since dealing with the heat generated in inefficient amplifiers.

C. Transit Characteristics of HEMT

Fig. 11 shows Drain Lag of HEMT with $L_G$ of 15 nm. The device exhibits excellent characteristics at the calculation of the drain obtained by simulation is 25%, we can say, however, that after analyzing the current delay is more pronounced when the trailing edge of the pulse drain the establishment of the drain current at high and low field. Fig. 12 shows Gate Lag of HEMT with $L_G$ of 15 nm. The device exhibits excellent characteristics at the calculation of the drain obtained by simulation is 26%.

This effect has its origin at the interface buffer / active layer HEMT; the electrons are injected into the buffer layer, where they are captured by the trap layer.

III. CONCLUSION

We have presented the power performance of 15 nm gate-length InAlN/GaN HEMTs on SiC substrates using the periphery oxide of the Gate. These devices exhibited current density as high as 0.59A/µm, Peak extrinsic transconductance of 0.85S/µm.

These results demonstrate the possibility of using this technology; we have presented an alternative explanation...
to the physical characteristics of the current pulses InAlN/GaN HEMT.

Resulting from structure InAlN/GaN of HEMT. The cover layer in addition to the drain and source with a Schottky layer analysis indicates that delay the speed of the simulation is to optimize atlas design to help the base property optimized.

References


Figure 5. Gain current $H_{21}$ of 15 nm InAlN/GaN HEMT with Temperature $T=300K$ and $V_{DS}=2V$.

Figure 6. Max Gain stable Power of 15 nm InAlN/GaN HEMT with Temperature $T=300K$ and $V_{DS}=2V$.

Figure 7. Unilateral Gain stable Power of 15 nm InAlN/GaN HEMT with Temperature $T=300K$ and $V_{DS}=2V$.

Figure 8. In and Out Power of 15 nm InAlN/GaN HEMT.

Figure 9. Power Gain of 15 nm InAlN/GaN HEMT.

Figure 10. Efficiency of 15 nm InAlN/GaN HEMT.
Figure 11. Drain Lag of 15 nm InAlN/GaN HEMT with Temperature T=300k, \( V_{GS} = 0 \text{V} \) and \( V_{DS} = 20 \text{V} \).

Figure 12. Gate Lag of 15 nm InAlN/GaN HEMT with Temperature T=300k, \( V_{GS} = -5 \text{V} \) and \( V_{DS} = 20 \text{V} \).