Investigation by scaling law of AlGaN/GaN Fin field effect transistors by device simulation

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Introduction

AlGaN/GaN based HEMT
• A gap of more than two orders of magnitude between the actual on-resistances and the theoretical limit
• Theoretical limit for the current state of the low-breakdown voltage
• Conventional scaling law based on the acceptor doping does not work

The advantage of material properties cannot be utilized

Simulation method

Simulation device structure

• Use of 2D model that view from top of the AlGaN/GaN 3D structure
• Setting scaling factor (K) and calculate as shrinking by 1/K
• Silvaco's Atlas was used for the calculation

Result and Discussion

Change of parameters by scaling factor K

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scaling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device size</td>
<td>1/K</td>
</tr>
<tr>
<td>Channel doping</td>
<td>K</td>
</tr>
<tr>
<td>Device Area</td>
<td>1/K²</td>
</tr>
<tr>
<td>Current density</td>
<td>K</td>
</tr>
<tr>
<td>R_C</td>
<td>1</td>
</tr>
<tr>
<td>Electric Field</td>
<td>1</td>
</tr>
<tr>
<td>Vth</td>
<td>1/K</td>
</tr>
<tr>
<td>I_dsat</td>
<td>1/K</td>
</tr>
</tbody>
</table>

• $I_{dsat}$ is defined as the drain current when gate voltage is 0 [V] and the drain voltage is 20/K [V]
• $R_c$ is calculated with Ohm's law on the drain current when the drain voltage is 0.5/K [V]
• Threshold is defined as the gate voltage when drain voltage is 20 [V] and $I_{dsat}/10^5$ [A]

The on-resistance increased remarkably with scaling down when the contact resistivity was considered. It shows that the contact technique is important as shown the difference from the ideal line.

V_th exhibited deviation from the ideal scaling behavior. This is probably due to assumption of constant work function of the gate electrode. The gate electrode technology is also important for future scaled down devices.