Characterization of N-polar GaN/AlGaN/GaN HEMTs on Sapphire by Metal Organic Chemical Vapor Deposition

Steve Xu Chen
Faculty advisor: Steven P. DenBaars
Mentor: , David F. Brown, Stacia Keller
Advantages of GaN

<table>
<thead>
<tr>
<th>Semiconducor (commonly used compounds)</th>
<th>Unit</th>
<th>Silicon</th>
<th>Gallium arsenide (AlGaAs/InGaAs)</th>
<th>Indium phosphide (InAlAs/InGaAs)ᵃ</th>
<th>Silicon carbide</th>
<th>Gallium nitride (AlGaN/GaN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandgap</td>
<td>eV</td>
<td>1.1</td>
<td>1.42</td>
<td>1.35</td>
<td>3.26</td>
<td>3.49</td>
</tr>
<tr>
<td>Electron mobility at 300 K</td>
<td>cm²/Vs</td>
<td>1500</td>
<td>8500</td>
<td>5400</td>
<td>700</td>
<td>1000-2000</td>
</tr>
<tr>
<td>Saturated (peak) electron velocity</td>
<td>X10⁷ cm/s</td>
<td>1.0</td>
<td>1.3 (1.0)</td>
<td>1.0 (2.1)</td>
<td></td>
<td>1.3 (2.1)</td>
</tr>
<tr>
<td>Critical breakdown field</td>
<td>MV/cm</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

ᵃIndium phosphide (InAlAs/InGaAs) is not a commonly used compound.
What is HEMT

- High cut off frequency
- High break down voltage
- High power density
- Low noise

Signal Amp

Steve Xu Chen - July 2009
Applications of GaN based HEMT

Wireless communication, mobile phone base station, satellite, radar etc.
• Epitaxial layer design
• Crystal growth (MOCVD)
• Material Characterization
• Device processing
• Device Characterization
High Al composition should increase the electron density in 2DEG
XRD data shows high quality GaN and AlGaN Epitaxial layer were grown. The reflected X-ray have different reflection angle.

Simulated Atom spacing of AlGaN > GaN
Smooth surface helps to reduce the electron scattering and increase the electron mobility

Well ordered steps were formed on the surface
High Al composition increases the sheet charge density
Electron mobility drops at high electron density
Total resistance = 2Rc + Rs
Rs = Slope of line = rL/dw

Low resistance is critical for high frequency performance
Devices parallel with the surface features show lower sheet resistance

Transistors should be fabricated parallel to the surface features
Large Gm is obtained and we expect good high frequency performance for this device. The device pinches off very well and it helps to improve high frequency performance.
Conclusion & Future work

• Good DC performance is achieved
• Low sheet resistance is reported
• High sheet electron density is obtained for high Al composition

Future work may include:
• Radio frequency measurement
• Capacitance-voltage characteristics
• Surface passivation