Ohmic Contacts for Wide Bandgap Devices

Zen Mehra  
Undergraduate Research Assistant  
Advisor: Dr. Shyh-Chiang Shen  
Assistant Professor

School of Electrical & Computer Engineering  
Georgia Institute of Technology

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Presentation Outline

• Introduction
• Background Study
• Research Objectives
• Process Design
• Results
• Future Work
• Acknowledgements
Introduction to Wide Bandgap Materials

• What are wide bandgap materials?

• The focus on GaN

• Some device applications

<table>
<thead>
<tr>
<th>Material</th>
<th>Si</th>
<th>GaAs</th>
<th>InP</th>
<th>GaN</th>
<th>AlN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lattice Constant</td>
<td>5.43</td>
<td>5.65</td>
<td>5.87</td>
<td>3.19</td>
<td>3.11</td>
</tr>
<tr>
<td>Bandgap(eV)</td>
<td>1.12</td>
<td>1.42</td>
<td>1.35</td>
<td>3.39</td>
<td>6.2</td>
</tr>
<tr>
<td>Breakdown Field (*10^6 V/cm)</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>&gt;2.5</td>
<td>n.a.</td>
</tr>
<tr>
<td>Saturation Velocity (*10^7 cm/s)</td>
<td>0.9</td>
<td>0.6</td>
<td>0.9</td>
<td>2.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Electron Mobility (cm²V/s)</td>
<td>1450</td>
<td>8500</td>
<td>4600</td>
<td>1000</td>
<td>135</td>
</tr>
<tr>
<td>Thermal Conductivity (W/cmK)</td>
<td>1.3</td>
<td>0.3</td>
<td>0.68</td>
<td>1.3</td>
<td>2.85</td>
</tr>
</tbody>
</table>
A brief background on ohmic contacts

- Definition of ohmic contacts
- Significance on circuit applications
- Electron transport mechanisms
- Layer structure
- Time-Temperature window

![Energy bands for n-type contact](image)

Background – past results from literature review and journal studies

- **p-type**
  - Pd/Au : $2.4 \times 10^{-5}$ Ω-cm²
  - Au/Ni : $10^{-2}$ to $10^{-6}$ Ω-cm²
- **n-type**
  - Ti/Al/Ni/Au : $8.9 \times 10^{-8}$ Ω-cm²
  - Ni/Au : $6.9 \times 10^{-6}$ Ω-cm²
- Appreciable linearity in I-V curve
- Surface Treatment – Cl₂, BCl₃, (NH₄)₂Sₓ
Research Objectives

• Experiment with different layer structures
• Establish optimum time and temperature conditions
• Aim for maximum linearity, lowest contact resistance
• Correlate results with initial data to draw meaningful conclusions

Process Design

• Preliminary Wafer Data
• Cleaning/Initial Treatment
• Photolithography
• Surface Treatment
• Metallization
• Annealing
• TLM Measurement
A Closer look at TLM measurement

- Details of measurement technique
- Data obtained after calculations

Preliminary Wafer Data

<table>
<thead>
<tr>
<th>Number</th>
<th>Type</th>
<th>Composition</th>
<th>Mobility (cm²/Vs)</th>
<th>Doping (cm⁻³)</th>
<th>Bulk Resistance (Ω-cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-0506-5</td>
<td>p</td>
<td>GaN:Mg</td>
<td>2.13</td>
<td>7.87×10¹⁷</td>
<td>3.72</td>
</tr>
<tr>
<td>2-0507-5</td>
<td>p</td>
<td>GaN:Mg</td>
<td>2.42</td>
<td>7.18×10¹⁷</td>
<td>3.59</td>
</tr>
<tr>
<td>2-1032-2</td>
<td>n</td>
<td>AlGaN</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>1-0906-2</td>
<td>n</td>
<td>GaN:Si</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>1-0722-5</td>
<td>n</td>
<td>GaN/AlGaN</td>
<td>55</td>
<td>2×10¹⁸</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Metallization Scheme

<table>
<thead>
<tr>
<th>Wafer</th>
<th>Metal</th>
<th>Thickness (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-0506-5</td>
<td>Ni/Au</td>
<td>200/200</td>
</tr>
<tr>
<td>2-0507-5</td>
<td>Ni/Au</td>
<td>200/200</td>
</tr>
<tr>
<td>2-1032-2</td>
<td>Ti/Al/Ti/Au</td>
<td>300/500/300/500</td>
</tr>
<tr>
<td>1-0906-2</td>
<td>Ti/Al/Ti/Au</td>
<td>300/500/300/500</td>
</tr>
<tr>
<td>1-0722-5</td>
<td>Ti/Al/Ti/Au</td>
<td>300/500/300/500</td>
</tr>
</tbody>
</table>

Results: p-type

Wafer Number: 2-0507-5
Anneal Conditions: 550°C for 50s
Specific Contact Resistance: 5.73*10⁻⁵ Ω-cm²
Regression Coefficient: 0.9970
Results: n-type

Wafer Number: 1-0722-5
Anneal Conditions: 850°C for 30s
Contact Resistance: $9.44 \times 10^{-7}$ Ω cm²
Regression Coefficient: 0.9901

Results: 2um

Extensive Non-Linearity
Schottky Behavior
Conclusions

• Doping Dependency
• Time-Temperature Window
• Process Factors
• n/p Variation for GaN

Future Work

• Continue experimenting with different layer structures/temperature/surface treatments

• Basis for fabrication of InGaN/GaN HBT that can sustain high temperature and voltage operation
Acknowledgements

• Dr. Shyh-Chiang Shen – Professor, advisor, mentor

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