Metal Gates for p-type GaAs Heterostructures

Brittany Hoard
Pennsylvania State University

Advisor: Dr. Michael Manfra
Purdue University
Molecular beam epitaxy system where GaAs wafers are grown
Goals

• GaAs/AlGaAs wafers – two-dimensional hole gas
• Create metal gated structures on p-type GaAs/AlGaAs wafers
  – Manipulate the two-dimensional hole gas
  – Shallow vs. deep wafers
• Conditions to test:
  – Different gate metals
  – Gate oxide
  – Photolithography vs. e-beam lithography
Overview

• 1. Characterize wafers
• 2. Ohmic contacts
• 3. Etching
• 4. Metal gates
1. Wafer Characterization

- Cut samples out of wafers
- Solder contacts onto samples
- Anneal contacts
- Graph magnetoresistance to obtain carrier mobility and density
Transport Data for a Shallow Wafer
2. Ohmic contacts

- Test Au/Be contacts and annealing conditions:
  - Evaporate contacts onto sample using metal mask
  - Cut large sample into smaller samples
  - Anneal contacts at various times
  - Test contact resistances
Thermal evaporator

Annealer
# Au/Be Contact Data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Annealing time</th>
<th>Au/Be thickness</th>
<th>Room temp. resistance (ohms)</th>
<th>4 K resistance (ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-10-05.1 (deep)</td>
<td>5 – 15 minutes</td>
<td>120 nm</td>
<td>11-14 k</td>
<td>40-100</td>
</tr>
<tr>
<td>6-29-11.1 (shallow)</td>
<td>5 minutes</td>
<td>61 nm</td>
<td>30-70 k</td>
<td>Non-ohmic</td>
</tr>
<tr>
<td></td>
<td>16 minutes</td>
<td>137 nm</td>
<td>40-80 k</td>
<td>80-100 k</td>
</tr>
<tr>
<td></td>
<td>5 minutes</td>
<td>137 nm</td>
<td>60-100 k</td>
<td>Insulating</td>
</tr>
<tr>
<td></td>
<td>5 minutes</td>
<td>112 nm</td>
<td>60-140 k</td>
<td>Insulating</td>
</tr>
<tr>
<td>10-21-03.1 (deep)</td>
<td>5 minutes</td>
<td>112 nm</td>
<td>40-90 k</td>
<td>Insulating</td>
</tr>
</tbody>
</table>
Au/Be Contact Problems

• Highly inconsistent results with the deep samples
• Consistently do not work with the shallow samples
• Factors involved:
  – Equipment cleanliness
  – Annealing time and temperature
  – Evaporation rate
  – Thermal evaporator vacuum
  – Au/Be thickness
3. Etching

- Photolithography tests
  - Photoresist
  - Exposure time
  - Developing time
- 30 seconds exposure found to be optimal for the MA-N2403 photoresist (10 second developing time)
Next Steps

• Resolve Au/Be contact inconsistencies
• Deposit gate metal
• Testing