Agenda

- DSG Overview
- DSG AXOM Tool
- DSG Process Applications:
  - Activation
  - Silicide Formation
  - a-Silicon Crystallization
Executive Team

DSG Overview

• Jeffrey Kowalski
• President/CEO of DSG Technologies:
  – 34 years Semiconductor Experience. Mostek.
  – Founded DSG Technologies in 2004
DSG Technologies

DSG Overview

- Founded 2005: California Corporation

- Private Equity Funded

- Development / Demo Center in Morgan Hill, CA
  - Development Systems in Class 10,000 Clean Room
  - Microwave Modeling Capability for New Materials

- Currently Working in Development Programs with >20 Customers:
Axom Tool Layout

Axom150 / Axom300
Low Temperature Activation

- Si, SiC, Sapphire Substrates
- Low Thermal Budget < 500°C Activation
  - Boron : Arsenic : Phosphorus
- Throughput > 50 WPH (300mm)
- Low Dopant Diffusion
- Patented Microwave Technique
  - Low Leakage
  - Effective with Low Dosages
Background

LTA

• In semiconductor materials, electrons move freely in response to the MW electrical field and an electric current results. The flow of the electrons will heat the material through resistive heating. The higher the resistance of the semiconductor material the higher the temperature it will reach. The average MW power per unit volume is converted to heat.
MW Efficiency

Axom 300

- Loss Factor represents the efficiency of microwave absorption in the wafer, as the loss factor decreases the efficiency of the microwave absorption decreases.

![Loss Factor - Si Wafer](image)

(N-type Wafer)
## P-Type Activation: Spike vs MWA

<table>
<thead>
<tr>
<th>PAI</th>
<th>Species: GE</th>
<th>$V_{acc}$: 15 KeV</th>
<th>Dose: $3 \times 10^{14}$ cm$^{-2}$</th>
<th>Main I/I</th>
<th>Species: BF2</th>
<th>$V_{acc}$: 1.5 KeV</th>
<th>Dose: $1.5 \times 10^{15}$ cm$^{-2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>1050°C</td>
<td>490°C</td>
<td>Rs (Ohm/Sq.)</td>
<td>665</td>
<td>720</td>
<td>STD DEV (%)</td>
<td>6.3</td>
</tr>
</tbody>
</table>
**P-Type Activation : Spike vs MWA**

- Comparable Mobility and Carrier Concentration even at Shallow Junction Depth

<table>
<thead>
<tr>
<th></th>
<th>Spike</th>
<th>MWA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rs (Ohm/sq.)</td>
<td>577</td>
<td>588</td>
</tr>
<tr>
<td>Hall Coef(m²/C)</td>
<td>1.58</td>
<td>1.90</td>
</tr>
<tr>
<td>Mobility(cm²/V·s)</td>
<td>27.4</td>
<td>25.3</td>
</tr>
<tr>
<td>Carrier Conc(cm⁻²)</td>
<td>3.95E+14</td>
<td>3.38E+14</td>
</tr>
</tbody>
</table>
Ge Epitaxy on Si

- Comparisons of Sheet Resistance on Ge Epitaxy Wafer Between RTA and Microwave.
- X-Ray Diffraction (XRD) Analysis
X-Ray Diffraction (XRD) Analysis

Axom 300

- RTA Will Degrade the Ge Crystal
- The Ge Signal Still Exists after Microwave Treatment
Sheet Resistance (Ohm/sq.)

Ge Epitaxy

<table>
<thead>
<tr>
<th>Method</th>
<th>320°C 100 sec.</th>
<th>400°C 100 sec.</th>
<th>500°C 30 sec.</th>
<th>600°C 10 sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTA</td>
<td>No Reading</td>
<td>1.10E4</td>
<td>6.18E3</td>
<td>5.30E3</td>
</tr>
<tr>
<td>Microwave</td>
<td>4.3E2</td>
<td>2.1E3</td>
<td>8.63E2</td>
<td></td>
</tr>
</tbody>
</table>

- On N-type wafer, BF₂ 15keV, 5E15 cm⁻²
- N type wafer, resistively: 2~10 Ω-cm
Activation: P-Type

- Total MW Power – 1st Order Condition to Drive Absorption Efficiency
- Average Power per Unit Volume is Converted to Heat

![Graph showing RsL vs Xj for MW Power Levels](Image)

- Conditions: GePAI + C + B 200eV
N-Type Activation : Leakage

- Leakage Reduced with Longer Dwell Time or Increased MW Power

Leakage Measurement

- MW Power A (450°C)
- MW Power B (500°C)
USJ Activation

USJ Activation with PAI: B 0.5keV, 5E14

<table>
<thead>
<tr>
<th>PAI Implant</th>
<th>Rs (ohm/sq.) Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 keV, 1E15</td>
<td>810</td>
</tr>
<tr>
<td>10 keV, 1E15</td>
<td>750</td>
</tr>
<tr>
<td>15 keV, 1E15</td>
<td>760</td>
</tr>
<tr>
<td>20 keV, 1E15</td>
<td>755</td>
</tr>
</tbody>
</table>

Without PAI: Rs = 6150 ohm/sq.
Nickel Silicide Formation

- Formation of NiSi 220°C
- Process time: 60 seconds
- Throughput >100 WPH (300mm)
- Reduced Leakage in Replacement RTP2
a-Si Crystallization Damage Recovery

Metal Gate anneal w/ Al

• MSM Capacitor Formation
• Image Sensor Damage Recovery
• Integration: Metal Gate ZrO2 Crystallization < 250C
• Single Crystal Ge Activation
Image Sensors – Damage Recovery

- DSG R&D Research Project for Next Generation Image Devices
- Recovery Levels equal to 1300°C RTP / Multiple Laser Steps
- Damage Recovery Improvement over Thermal Anneal

1300°C Standard Anneal
Si Implant 70 keV

600°C MW Anneal
Si Implant 70 keV