Rapid Thermal Processing (RTP)

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OUTLINE

Introduction
Equipment
Processes for:
  Activation of Ion Implanted Impurities
  Rapid Thermal Processing of Dielectrics
  Silicidation and Contact Formation
  Thermoplastic Stress
References
**INTRODUCTION**

Rapid Thermal Processing (RTP) can be used to reduce the thermal redistribution of impurities at high temperature. For small devices this is an important consideration and as a result most engineers make use of low temperature processes. Some ion implants require high temperature (at least 1000 °C) thus RTP is a promising technology.

RTP was originally developed for ion implant anneal but has broadened its application to oxide growth, chemical vapor deposition, and silicidation.
RAPID THERMAL PROCESSING (RTP)
RAPID TEMPERATURE RISE

- ±2 °C Ramp
- ±0.5 °C Soak
- Desired Temperature

Time (sec)

Temperature (°C)

Rapid Temperature Rise Chart
Figure 8-28 Schematic of a closed-loop temperature control system. Courtesy of Applied Materials, Inc.
From Textbook by S. Wolf

Textbooks say that 150Å of oxide can be grown by RTP at 1100°C in 60 sec.

**Figure 6-13** Typical data for oxide thickness as a function of time for a rapid thermal oxidation process (after Moslehi et al., 1985).
RTP THIN OXIDE GROWTH

Poly

1.8 nm Oxide

1.8 nm

Silicon
Recipe for RTP Oxide, time during SS (Steady State) was changed to obtain different oxide thicknesses, 60s, 120s, 240s, and 480s

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (sec)</th>
<th>Temp (C)</th>
<th>T sw</th>
<th>Gain</th>
<th>Dgain</th>
<th>Iwarm</th>
<th>Icold</th>
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<tr>
<td>Ramp</td>
<td>120</td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SS</td>
<td>10</td>
<td>1000</td>
<td>20</td>
<td>-250</td>
<td>-60</td>
<td>5500</td>
<td>5500</td>
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<tr>
<td>SS</td>
<td>480</td>
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<td>20</td>
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Sébastien Michel, February 2005
Steve Parshall, Kazuya Tokunaga, May 2005
### OXIDE THICKNESS MEASUREMENTS

The data shown was obtained using the 5 point 6” wafer Spectromap.

<table>
<thead>
<tr>
<th>Time</th>
<th>8</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>Min.</th>
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<tr>
<td>Mean</td>
<td>211.53</td>
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<td>104.29</td>
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<tr>
<td>Max</td>
<td>271.26</td>
<td>174.22</td>
<td>132.36</td>
<td>71.245</td>
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<tr>
<td>Min</td>
<td>167.06</td>
<td>130.35</td>
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<td>STDDEV</td>
<td>37.112</td>
<td>20.187</td>
<td>28.929</td>
<td>14.234</td>
<td>%</td>
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<td>Center Pt</td>
<td>271.26</td>
<td>174.22</td>
<td>132.36</td>
<td>71.245</td>
<td>A</td>
</tr>
</tbody>
</table>

RTP Oxide at 1000 C, Dry O2

The data shown was obtained using the VASE (Variable Angle Spectroscopic Ellipsometer).

<table>
<thead>
<tr>
<th>Time</th>
<th>8</th>
<th>4</th>
<th>2</th>
<th>1</th>
<th>Min</th>
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<td>Xox</td>
<td>272.54</td>
<td>167.59</td>
<td>143.03</td>
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<tr>
<td>n</td>
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<td>1.45</td>
<td>1.45</td>
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RTP OXIDE QUALITY MEASUREMENTS

Measurements made using the SCA (Surface Charge Analyzer)

<table>
<thead>
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<th>8 minutes</th>
<th>4 minutes</th>
<th>2 minutes</th>
<th>1 minute</th>
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</thead>
<tbody>
<tr>
<td>NSC</td>
<td>1.13E+14</td>
<td>1.64E+14</td>
<td>1.46E+14</td>
<td>7.56E+14</td>
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<tr>
<td>Qox</td>
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<td>4.26E+11</td>
<td>4.28E+11</td>
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<tr>
<td>Dit</td>
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<td>3.05E+11</td>
<td>4.32E+11</td>
<td>4.13E+11</td>
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<tr>
<td>Qfb</td>
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<td>5.53E+11</td>
<td>5.94E+11</td>
<td>7.05E+11</td>
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<tr>
<td>Ts</td>
<td>83</td>
<td>78</td>
<td>126</td>
<td>151</td>
</tr>
</tbody>
</table>

Dit is close to Bruce Furnace thermal gate oxide values
Typically ~1E11
ULTRA SHALLOW JUNCTION FORMATION

Figure 4. (Left) Concentration profiles (measured via SIMS) for 2.2 keV, BF₂⁺, 1 × 10¹⁵/cm² implants using 30-sec and 50-sec processes. Figure 5. (Center) Concentration profiles (measured via SIMS and SRP) for 2.2 keV, BF₂⁺, 1 × 10¹⁵/cm² implants using a 1075°C/20-sec process. Figure 6. (Right) Fluorine depletion before and after anneal.
SILICIDE AND BARRIER LAYER FORMATION

Silicide formation includes Ti, Pt, W, Ta, Mo, and Co. TiSi₂ is formed at 900 °C in pure N₂. Titanium is sensitive to H₂O and O₂ in the ppm levels.

TiN barrier layers can be formed by reacting Ti with N₂ or NH₃.
Uniformity of temperature across the wafer is the most important parameter. Local across the wafer temperature gradients cause stress.
Lamp based RTP systems have been the choice for the past several years. Special physical configurations have used to provide additional heat towards the outer edge of a round wafer. These systems are cold wall systems so more power is needed at the wafer edge than in the center of the wafer.
In the susceptor-based, hot-wall system, heating is achieved by placing wafers in close proximity to a heated thermal mass and thereby heating the wafers with a uniform flux of relatively long wavelength radiation. In such a system, the initial temperature ramp-up rate increases with increase in process temperature. Heat-up and cool-down rates in excess of 100 °C/sec.
**FACTISI1.RCP (step 1 – form TiSi)**
- Delay 30 sec.
- Ramp 75 °C/sec. To 650°C
- Steady State 60 sec. at 650°C
- Ramp 125°C/sec. To 300°C

**FACTISI2.RCP (step 3 – form TiSi₂)**
- Delay 30 sec.
- Ramp 75 °C/sec. To 800°C
- Steady State 60 sec. At 800°C
- Ramp 125°C/sec. To 300°C

**Etching of Ti Metal (step 2)**
Heat the Sulfuric Acid:Hydrogen Peroxide (1:2) mixture on a hotplate to 100°C (set plate temperature to 150°C)
Etch for 1 min 30 sec. This should remove the Ti that is on top of the silicon dioxide but not remove TiSi that was formed on the polysilicon and D/S regions. It also removes unreacted Ti metal over the TiSi on the poly and D/S regions.
SUMMARY

Rapid thermal processing was developed to enable short time high temperature implant annealing. Generally, the wafer rests on quartz pins in a flow tube and is heated using a bank of high intensity filament lamps.

Problems with RTP include temperature measurement and thermal uniformity of the wafer. Excessive temperature gradients across the wafer cause thermoplastic stress that may lead to wafer warpage and/or slip. Rapid thermal processing has been extended to include silicide and barrier metal formation, thermal oxidation, chemical vapor deposition, and epitaxial growth.
REFERENCES

HOMEWORK - RTP

1. Describe the application of RTP for ion implant anneal.
2. Discuss why RTP would be good for gate oxide growth.